A STUDY OF PLANTATION ESTABLISHMENT ON THE QUABBIN RESERVOIR WATERSHED

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master in Forest Science at Harvard University

Harvard Forest

Petersham, Massachusetts

September, 1960

ACKNOWLEDGMENT

The author is indebted to the director and staff of the Harvard Forest for their guidance and many valuable suggestions during both the field work and preparation of the manuscript. Also, to Mr. Russell Snow, Forest Manager, Quabbin Reservoir Watershed, for making available the maps and records of reforestation on the Quabbin Reservoir Watershed.

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INTRODUCTION

The planting of forest trees on poorly stocked and non-forested land has been practiced since forestry came into existence in the United States. Smith (1956) stated that, by 1954, the three southern New England states had planted an estimated 171,000 acres with forest trees.

In southern New England, the reasons for planting forest trees are numerous and vary from aesthetic improvement of the site to the eventual production of commercially valuable forest products. Regardless of the reason, the fact remains that once the trees are planted, they must be cared for through the use of such silvicultural measures as weeding and releasing if the area planted is to be completely dominated by these trees.

The Society of American Foresters (1950) define an established plantation as one which is adequately stocked and requires no further general weeding, and one in which the young trees are almost certain to survive normal adverse influences. If this definition of established plantations is accepted, we can find many texts and publications which discuss the silvicultural treatments needed to ensure establishment. There is, however, a definite lack of published information and data which indicate how much of a planted area can be expected to become established under different intensities of silvicultural management, and this is especially true in the southern New England states. There is also very little published information that shows how much effect "normal adverse influences" exert on the establishment of plantations in southern New England.

This author has been involved in several forest planting programs in southern New England and has felt the need for more information concerning plantation establishment. This investigation presents observations and data collected on approximately 3,200 acres on the Quabbin Reservoir Watershed in central Massachusetts, planted with forest trees and silviculturally managed at low intensity, and it describes how much of the planted area became established and what factors caused failure of establishment. Low intensity of silvicultural management, in this study, is described as no further silvicultural treatment after planting until a thinning can be made on the area at no cost, or with some financial return being realized.

It must be acknowledged that the results of this investigation do not apply to the entire southern New England area but it is believed that many patterns of fact encountered in the study area are applicable throughout much of southern New England.

THE PROBLEM

Purpose:

The study area comprises 3,223.9 acres planted with white pine, red pine, European larch, eastern hemlock, white spruce and Norway spruce during the years 1935 through 1943. This planted area has received no silvicultural treatment, subsequent to planting, until the plantations could be commercially thinned. Commercially thinned, in this study area, means that thinnings were carried out without cost to the land-owner and there was some financial return from the sale of the material removed during the thinning. The purpose of the present investigation is to determine how much of the study area became established with planted trees and to investigate reasons why some of the planted areas failed to become established.

Established:

The term "established", as defined by the Society of American Foresters (1950) is exceptionally general in scope, and is stated as follows:

> "Applied to a plantation when adequately stocked and requiring no further general weeding, and in which the young trees are almost certain to survive normal adverse influences".

This definition, of necessity, must include a great variety of conditions. Adequately stocked can mean many things to a forest-land manager depending upon varying circumstances, and the decision as to whether a plantation is satisfactorily stocked must be left to the discretion of the person concerned with the planted land. The forest-land manager must also decide

when a plantation is "almost certain to survive normal adverse influences". This could vary from region to region and also from one planted area to another within a region.

For the purpose of this investigation, it was felt that this definition of establishment required too much subjectivity on the part of the investigator. A more objective criterion was chosen which described the percentage of planted area dominated by the crowns of planted trees. This shows the proportion of the area which has been taken over by planted trees 17 to 24 years after planting, but does not inject judgement as to the degree of stocking required to be called "adequate". This criterion is much more objective because there are photo interpretation techniques which provide a rapid and standardized method of judging the proportion of planted tree crowns dominating an area in terms of percent of crown closure.

For the purposes of this study, the definition of an established plantation is:

> A plantation in which the crowns of the planted trees completely dominate the vegetative or crown cover of the entire planted area.

This author proposes that plantations in this age group can be established in varying degrees depending upon the percent of crown closure. Therefore, percentage of crown closure and percentage of establishment are considered to be synonymous.

Excellent aerial photographs of the area were available and it was decided that a judgement as to the degree of crown closure, or establishment, in the planted areas could best be made through photo interpretation supplemented by field inspection.

With this system of determining the degree of establishment, the forest-land manager is not compelled to accept an investigator's judgement, but can decide for himself what crown closure class is acceptable.

There are several advantages in studying a large area to determine degrees of establishment in plantations:

1. A large area such as the one in this investigation will probably include a wide variety of site conditions where trees were planted.

2. Theoretically, a large planted area could contain all degrees of establishment, equally represented, throughout the planted area. If this is not the case, a study of a large area should point out similar sites having high and low percentages of establishment and this would indicate the places where factors limiting plantation establishment have been most effective.

3. Having let the planted trees integrate the various factors influencing crown closure, the study of a large area allows the investigator to know where to look for the greatest impact on plantation establishment.

Previous Land-Use:

The land which was planted in this study area was used for three different purposes prior to the time of planting. Agriculture had been the main industry in the area and all of the forest tree planting was done on land which had been recently cultivated, pastured with livestock, or had been retired from intensive agricultural use for a relatively short time (1 - 15 years) and supported a relatively dense growth of woody vegetation.

Raup and Carlson (1941) suggest that previous land-use had a definite influence on forest composition in central Massachusetts. It is very prob-

able that previous land-use will affect plantation establishment as well. Therefore, it was felt that a study should be made to determine if the varying degrees of establishment were associated in any way with the nature and intensity of use to which the land had been subjected prior to the planting of trees.

Factors Affecting Plantation Establishment in the Study Area:

Due to the fact that a relatively large area was selected for investigation and the amount of time to be devoted to this study was limited, only the more obvious factors affecting plantation establishment were examined.

The photo interpretation and field inspection indicated that the primary factors involved in plantation establishment were deer damage, porcupine damage, physical characteristics and drainage of the soils, and competition. Rudolph (1950) defines competition as; "the effect upon the planted trees of the demands of other closely adjacent trees, brush, or sod for the same space, light, soil moisture, and soil nutrients"; and this is the concept of competition which has been used in this study.

The primary purpose in examining the above factors was to determine the extent to which each of these factors affected the overall percentage of establishment in the study area. It was hoped that patterns of fact would develop from this examination which would help to explain the primary causes for plantations failing to become established in some areas.

REVIEW OF THE LITERATURE

Establishment:

There is very little published information available concerning the degree to which planted areas, in southern New England have become established plantations. This is especially true in plantations which have received no silvicultural treatment subsequent to planting.

Hawley (1924) found that approximately one-half of the 14 year old plantations on the New Haven Water Company Holdings, in southern Connecticut, required cleanings[1] if they were to become established. On the Eli Whitney Forest, New Haven, Connecticut, Hawley and Lutz (1943) estimated that 15 percent of the open old field plantings needed cleanings to remove undesirable overtopping vegetation and one-half of these areas would need a second cleaning to become established. They also estimated that three to four cleanings would be needed to free conifers from competition on cut-over hardwood land. These conclusions were based on examination of plantations which were 14 years of age and older.

Spurr (1956) noted that, at the Harvard Forest, Petersham, Massachusetts, plantations on open land were successfully established, with one cleaning needed in 56 percent of the plantations. Those on semi-open land needed at least one cleaning each, and those on cut-over lands needed from two to five cleanings to become established. He also reported that, "plant-

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[1] Cleaning is defined by the SAF (1950) as: "An operation in a young stand, not past the sapling stage, (a) to free small trees as in plantations from weeds, vines or sod-forming grasses, and (b) to provide better growing conditions by liberating crop trees from other individuals of similar age but of less desirable species or form which are overtopping or likely to overtop them. Syn. Disengagement cutting; Weeding."

ing site is most important" on cut-over land. Red pine, Scotch pine and European larch were the only species capable of dominating excessively drained sites and Scotch pine and European larch could not do this consistently. White pine dominated a site only on areas of "less extreme drought and fertility". Norway and white spruce were not successful on imperfectly drained soils or excessively drained soils. Plantations upon which these conclusions were based were from ten to thirty years old.

The above reports are based on planted areas which were under intensive silvicultural management and received intermediate cuttings when needed. There is an indication that if silvicultural measures had not been carried out in these areas many plantations probably would not have become established, especially in the cut-over woodland. There is, however, no estimate of how much of the total planted area in these studies became established.

In a field study of 999 acres of white and red pine plantations in Cheshire County, New Hampshire, House (1955) estimated that 27 percent of the acreage inspected had such low economic possibilities that no further forest improvements could be justified. Weevil damage, poor site, and low survival were considered as the factors causing this condition. The author judged that 60 percent of the acceptable plantations in this area were in need of weeding or releasing[1] if they were to become successfully established.

"Worthless" hardwoods occupied from five to thirty percent of the canopy in these plantations which were twenty years of age and older. The author does not indicate that these plantations had received weedings or

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[1]Release is defined by the SAF (1950) as: To free trees from competition or otherwise removing or killing nearby vegetation and branches. Usually applied to young stands.

cleanings.

Zillgit and Rotty (1955) state that, in New England, 62 percent of the total area planted through 1952 is classified as acceptable. They define an acceptable plantation as one which, at the end of the fifth year, had 400 planted trees per acre. This estimate encompasses all plantations in New England, and includes those which have received silvicultural treatment after planting as well as those which have not.

The literature cited has little to relate concerning the percentage of plantation establishment found in planted areas in southern New England, or the extent to which any one of several adverse factors may have affected plantation establishment.

The literature review that follows concentrates on the factors which have influenced plantation establishment on the Quabbin Reservoir Watershed. Each of the factors listed on page six is dealt with separately.

Deer Damage:

The New England Section, SAF (1931) stated that deer damage to forest stands is light or negligible in northern and central Massachusetts. However, damage to individual trees can vary from an occasional nipped leader to complete elimination of new growth. The only species reported to be immune in this area is white spruce. Frontz (1930) reported that, in Pennsylvania, damage from deer browsing has been so serious in plantations that it was recommended that no attempt should be made to plant conifers or hardwoods in any area where there is an abundance of deer. Deer feeding on the buds, leaves and succulent twigs, killed and deformed large numbers of trees in the younger plantations. Stiell and Farrar (1953) noted that, in Canada,

deer did not browse red pine seriously and damage to this species was negligible.

Porcupine Damage:

Hosley (1938) stated that the porcupine is reputed to do more damage to forest trees than any other animal in New England. In the winter, the porcupine eats the bark and needles of trees. They do not appear to have a distaste for any tree species but they seem to build up different preferences in different localities. Hosley also noted that, at the Harvard Forest, the porcupine had practically eliminated European larch. All trees are susceptible from early life to maturity and damage may vary from the removal of small portions of the bark and living cortex to complete debarking of the whole tree. Injury is most common on trees located adjacent to ledges, stone walls, or old cellar-holes which provide cover for the porcupines. Dead and dying trees close to the porcupine dens are of common occurrence and stagheadedness is a characteristic of porcupine damage since these animals seem to prefer the thin bark in the tree tops (Hosley, 1938 and New England Section, SAF, 1930).

Physical Characteristics and Drainage of Soils:

The physical nature of soil as it affects aeration and drainage, seems to have a profound influence on the establishment of plantations. Stone, Morrow, and Welch (1954) attributed the stunting and dying of red pine in New York to deficient soil aeration during long periods of soil saturation. Coile (1952) points out that root growth is affected markedly by soil texture, permeability, aeration, infiltration, stoniness, and organic matter content. He further notes that other research workers have related poor internal drainage to the failure of coniferous plantations.

Rudolph (1950) states that, in the Lake States, some 400 soil types have been recognised, but for reforestation purposes these types are classified into seven broad soil groups based on texture and moisture. These range from the excessively drained sandy soils on one extreme to poorly drained organic soils at the other.

One can conclude from a review of the literature on the relationship between soil properties and plantation establishment that, in this region, chemical properties of the soil probably exert very little influence on plantation establishment, whereas the physical properties which influence moisture regimes in the soil can affect the survival and growth of planted trees to a great degree. It would seem feasible to establish plantations on any area where soil-moisture regimes are favorable to the species planted.

Competition:

Rudolph (1950) states that competition, as defined on page six, is probably the most important factor preventing the establishment of plantations. He indicates that this is most important because it is most frequently encountered as the factor adversly affecting establishment.

Hawley (1924) found that after planting trees in abandoned cultivated fields and pastures, in southern New England, deciduous tree species begin to seed in between the planted trees and frequently over-top the planted conifers. This will retard the growth and "even kill" the planted trees "in certain cases". He further noted that deciduous tree competition was particularly severe on the moister sites, burned over land, or heavily pastured areas and that deciduous species such as grey and black birch,

alder, and others develop with remarkable speed on bare lands.

Hawley and Lutz (1943) suggest that old-fields sometime contain small deciduous seedlings which are bare of leaves in late fall and early spring. These may be overlooked when an area is inspected as a possible planting site. They recommend that these areas should not be planted but should be left to develop into natural hardwood stands.

Roe (1955) reports that some plantations in the Lake States suffer from the competition of perennial forbs and grasses but that most of the competition is from shrubs and weed trees. He suggests that if such competitors are not controlled, many of the planted trees will become suppressed and poorly formed. In extreme cases this will mean complete loss of plantations.

Many investigators commenting on competition in plantations have recommended that the under-planting of brushland and cut-over hardwood land should not be undertaken unless it is economically feasible to control or eliminate hardwood competition at least until the plantation has become established (Tryon, 1932; Simonds, 1952; Roe, 1955; and Lower Michigan Chapter, SAF, 1960).

This review of literature pertaining to plantation establishment has noted only the publications which most completely cover the subject and are most pertinent to the study area here involved. Many more publications exist which discuss, in part, various problems encountered in forest tree planting and if further information is desired, the selected bibliography contained in Appendix C should be reviewed.

THE STUDY AREA

Historical Background:

In 1926, an act of the Massachusetts Legislature provided for the extension of the water supply system for the Metropolitan District of Boston and the Metropolitan District Water Supply Commission was established under the then existing Metropolitan District Commission. This Commission was to supervise the construction of the Quabbin Reservoir and the aqueduct needed to carry the water from the Quabbin Reservoir to the Wachusett Reservoir in Clinton, Massachusetts. The Wachusett Reservoir was to be used as a storage reservoir for water prior to its being conducted to the Boston area through the newly constructed Sudbury works and the old Cochituate Water supply line (Howe, 1951).

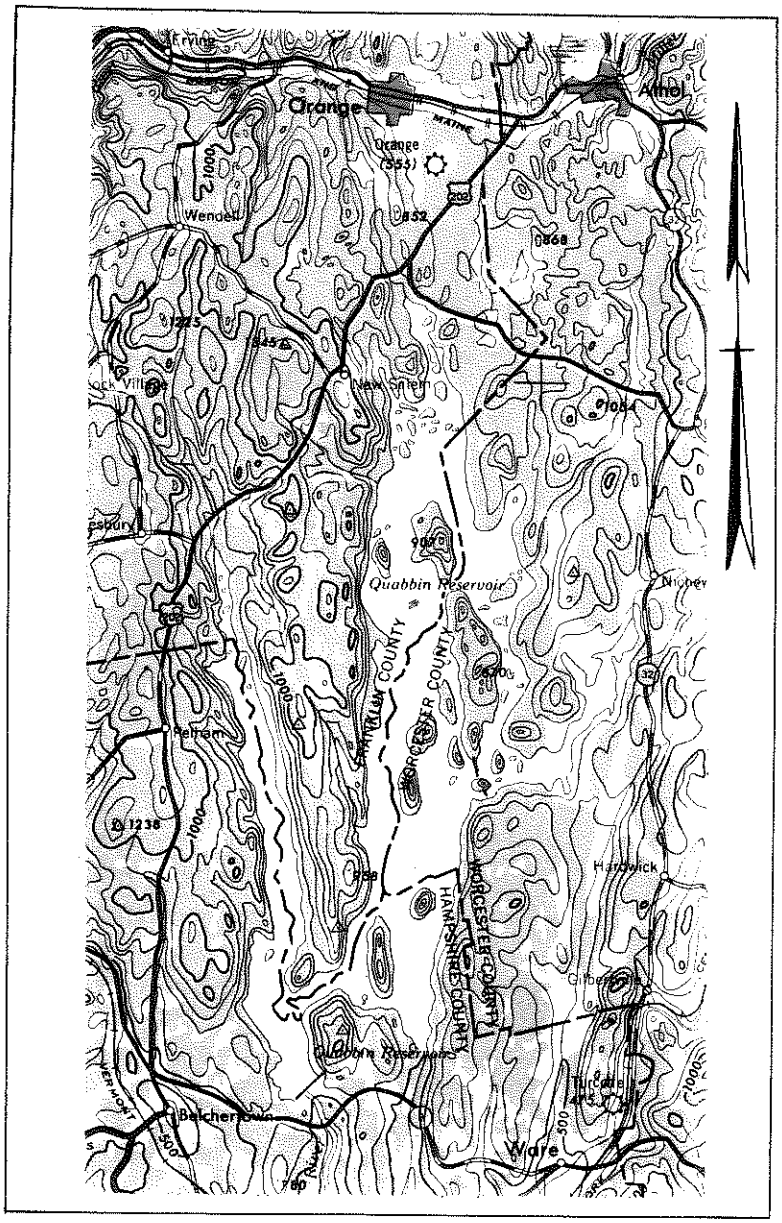
Previous investigations of water resources in the State of Massachusetts revealed that the most desirable site for the new reservoir was located in the Swift River Valley in the west-central part of the State. The area required for inundation and watershed protection would include all of the towns of Dana, Enfield, Greenwich and Prescott; and also portions of the towns of Belchertown, Ware, Barre, Petersham, Hardwick, Orange, Wendell, New Salem, Shutesbury, and Pelham (Snow, 1946).

The Watershed:

Approximately 83,500 acres of land located in the Swift River Valley and the surrounding hills had been acquired by 1941. This area now comprises the Quabbin Reservoir and Watershed. Most of the watershed, and the area

FIGURE I

General Location of the Quabbin Reservoir Watershed.



The study area is located on the large penninsula extending south through the reservoir, along the western shore of the reservoir and to the northeast of the reservoir. Map taken from USGS - Eastern United States, 1 : 250,000, No. NK 18-6.

utilized in the present study, is located within the boundries of U.S. route 202 from Belchertown to Orange on the west, Massachusetts route 122 from Orange to Petersham on the north, Massachusetts route 32 from Petersham to Ware on the east, and Massachusetts route 9 from Ware to Belchertown on the south (See Figure I).

The topography of the watershed is typical of central and southern New England with its smooth, gently rolling hills oriented generally north and south, and small valleys or swales scattered here and there among the hills. Elevations on the watershed range from 380 feet above sea level at the base of the Winsor Dam to 1281 feet at the top of Packard Mountain in the former town of Prescott.

Soils on the watershed are primarily derived from glacial till with a few small areas from glacio-fluvial outwash and water-washed till located principally in the former town of Dana. These soils are derived from granitic and schistose bedrock which underlies the general watershed area (Emerson, 1917).

The climate is typical of the continental climate found in the surrounding area. Temperatures in 1959 ranged from 9.8° F to 85.7° F[1]. Temperatures have been known to be as low as -20° F and as high as 103° F in the general area[2]. The average annual precipitation from 1930 to 1959 on the watershed was 46.38 inches[2]. Rasche (1958) states that the area has approximately 137 frost-free days annually.

[1, 3] Information received from Quabbin Reservoir Watershed Headquarters, August 26, 1960.

[2] The author's experience.

Reforestation on the Watershed:

Because one of the primary industries in this area prior to the acquisition of land for the reservoir was agriculture, much of the land preempted was open and semi-open farmland;

> "...some 10,000 acres consisted o arable land, pasture, brush-land and gray birch sprout-land.[1] Rather than allow this land to grow up to worthless brush and inferior species of deciduous or leaf-bearing trees, the Commission decided to organize a reforestation program, to plant these areas to coniferous or needle-bearing trees, for the purpose of better protection to the watershed, and at the same time to establish a watershed forest, which would some day produce a revenue from mature stands of timber.
>
> The protection to the watersheds of reservoirs, afforded by reforestation with coniferous trees, is the prevention of the growth of deciduous trees, which will take place on these areas through natural reproduction, and the elimination of leaves blowing into the water, which results in a high color and taste in the water from the decomposition of this organic material.
>
> Coniferous forests also tend to conserve the moisture in the soil by preventing evaporation and too rapid run-off of precipitation on the watershed." (Snow, 1946).

A plan was established in 1934 to carry out the reforestation of these open and semi-open lands on the watershed and to accomplish the management objectives outlined by Snow above. A forest nursery was established which would provide approximately three million coniferous transplants annually. Planting started in 1935 with nursery grown 3-2, 3-3 and 2-1 transplants purchased from private and public nurseries during the three year period it took to raise transplant stock in the Quabbin Nurseries.

From 1935 to 1946, some ten million trees were planted on approximately 9,000 acres located on both the Quabbin and Ware River Watersheds. Approximately two-thirds of the planted acreage is located on the Quabbin Reser-

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[1] This 10,000 acres includes areas in both the Quabbin and Ware River Watersheds. This study does not include the plantations in the Ware River area.

voir Watershed. The species planted were red pine, white pine, European larch, Norway spruce, white spruce, red spruce, hemlock and Scotch pine. The Scotch pine was experimentally planted and only a few small areas were stocked with this species. Some deciduous species were also planted but these were not analyzed in this study.

The trees were planted by large crews, sometimes as many as 22 men. All trees were planted by the slit method using the Harvard Forest Planting Tool. The planting crews averaged 900 to 1,000 trees planted per man-day and the initial survival averaged 30 to 95 percent. There were very few plantations which had an initial survival rate lower than 90 percent, and those with very low survival had supplementary plantings within two seasons (Snow, 1941). It is assumed that supplementary plantings were successful, as planting records do not state otherwise.

One of the most commendable aspects of this large reforestation project, from a research point of view, is the fact that excellent records were kept, in considerable detail, of each area. The records consist of maps on a scale of 1" = 200' and 1" = 2,000', detailed records showing the number of trees planted and the cost per thousand on a week by week basis, periodic summaries of the progress of reforestation work, and photographs of some of the planted areas. In a few areas, photographs were taken during the first Fall after planting and again four to five years later.

One other aspect which is important is the fact that the forest-land Manager, Mr. Russell Snow has been with the Metropolitan District Commission since the acquisition of land for the Quabbin Reservoir. His close personal knowledge of the problems encountered and the techniques utilized in

this reforestation project has been of invaluable assistance to the completion of this research project.

This watershed offers one of the best opportunities for forest plantation research in New England. The planted area is readily accessible because the major roads in the abandoned towns have been maintained for fire protection and the roads which have not been continuously maintained are still traversable by jeep. Most of the plantations are close to these old roads because much of the area planted is abandoned agricultural land located adjacent to the roads. Practically all species believed adaptable to central and southern New England have been planted on this watershed. Reforestation has been attempted on a wide range of planting sites which include arable land, pasture, and sproutland located at elevations which span a range of approximately 1,000 feet on all aspects, all slope positions and on at least four land-drainage classes.

PROCEDURE

Establishment:

It was felt that the study should include as much of the planted area, which had received no cultural treatment subsequent to planting, as was possible to examine in the time allotted for the investigation. This would insure that a large sample of the varying planting sites would be considered. Also, it would increase the probability that patterns of fact would emerge which might help to explain varying percentages of establishment on different planting sites.

Avery (1957) states that devices for checking crown closure, or establishment, on the ground are considered unsatisfactory. For this reason, and the fact that it was desirable to analyze a large area in a minimum amount of time, aerial photographs were utilized to the fullest extent.

The latest aerial photographic coverage of the area was obtained from the Massachusetts Department of Natural Resources, Division of Forests and Parks. These photographs were taken during the summer seasons of 1951 and 1952. The scale is 1 : 20,000 or 1" = 1,666.6' and their quality is excellent.

A ground reconnaissance of the study area was made to familiarize the investigator with the area and, at the same time, to determine the suitability of the aerial photographs for estimating the percentage of crown coverage. It was found that these photographs were satisfactory for determining establishment percent in pine and hemlock plantations 17 years or

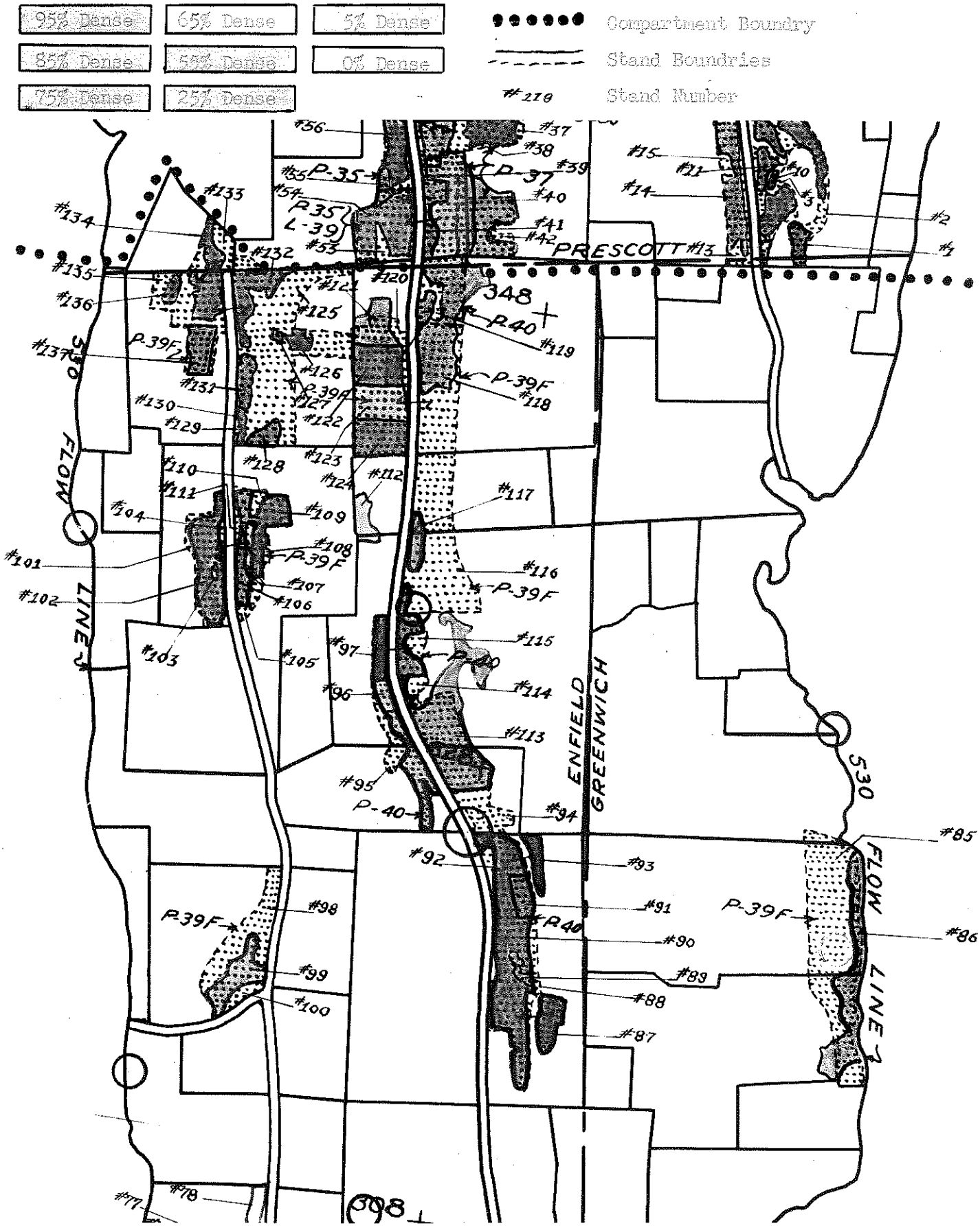
older, and in spruce plantations which were 20 years of age or older. Plantations in younger age-classes could not be used because they were so young at the time of photographing that their appearance on the photographs could not be correlated with the obvious percentage of crown closure achieved since.

There is some information on the performance of southern New England plantations which have been treated with various silvicultural prescriptions throughout their early life (Allardice, 1909; Hawley, 1924; Miller, 1934; Hawley and Lutz, 1943; Lutz and Cline, 1947; Lockard et.al., 1959). Because of this fact, this investigation is concerned only with those plantations which received no silvicultural treatment after planting until they were old enough to be commercially thinned. The ground reconnaissance aided in the selection of untreated plantations because the silviculturally treated areas were eliminated at this time.

With the use of the aerial photographs, the next step was to identify each area supporting a stand of planted trees which appeared to be in a different crown closure class. This was accomplished by viewing the photographs stereoscopically and outlining each of these areas with a soft lead pencil. With the use of the Multiscope the outlines of these areas were transferred to a base map, scale 1" = 20 chains, showing the original planted areas. By overlaying the stands shown on the photos, on the maps showing the original planted areas, the stands having zero percent density were also identified because this transfer of detail from photo to maps clearly indicated the areas where planted trees do not dominate the original planted area.

FIGURE II

Identification of Stands and Their Crown Densities



The planted areas were divided into six compartments for convenience and each identified stand, within the compartments, was assigned a stand number, including those stands which had zero percent density of planted trees (Figure II).

In order to classify the numbered stands as to percent of crown closure, the photos were again viewed with a stereoscope, and looking through a transparent crown density scale developed by the Central States Forest-Experiment Station, the stands were classified in eleven different density percentages from 0 to 95 percent. Each density class was assigned a color and each numbered stand was colored to show its density (Figure II). Stands with zero percent density were left uncolored.

As a result of this preliminary investigation, it was possible to identify 952 separate stands, each with its own percentage of crown closure, or percent of establishment. A polar planimeter was used to determine the acreage within each of these stands. The sorting and manipulation of data for each stand was simplified by punching this information on a Royal McBee Keysort punch-card. The data included for each stand is shown in Figure III.

Previous Land-Use:

The study area plantations were located on land with three major types of previous use. The Metropolitan District Commission had classified the land into arable, pasture, sproutland, and woodland during the land aquisition; and trees were planted on the first three types of land during the reforestation program.

The three land-use types found in the study area were defined as:[1]

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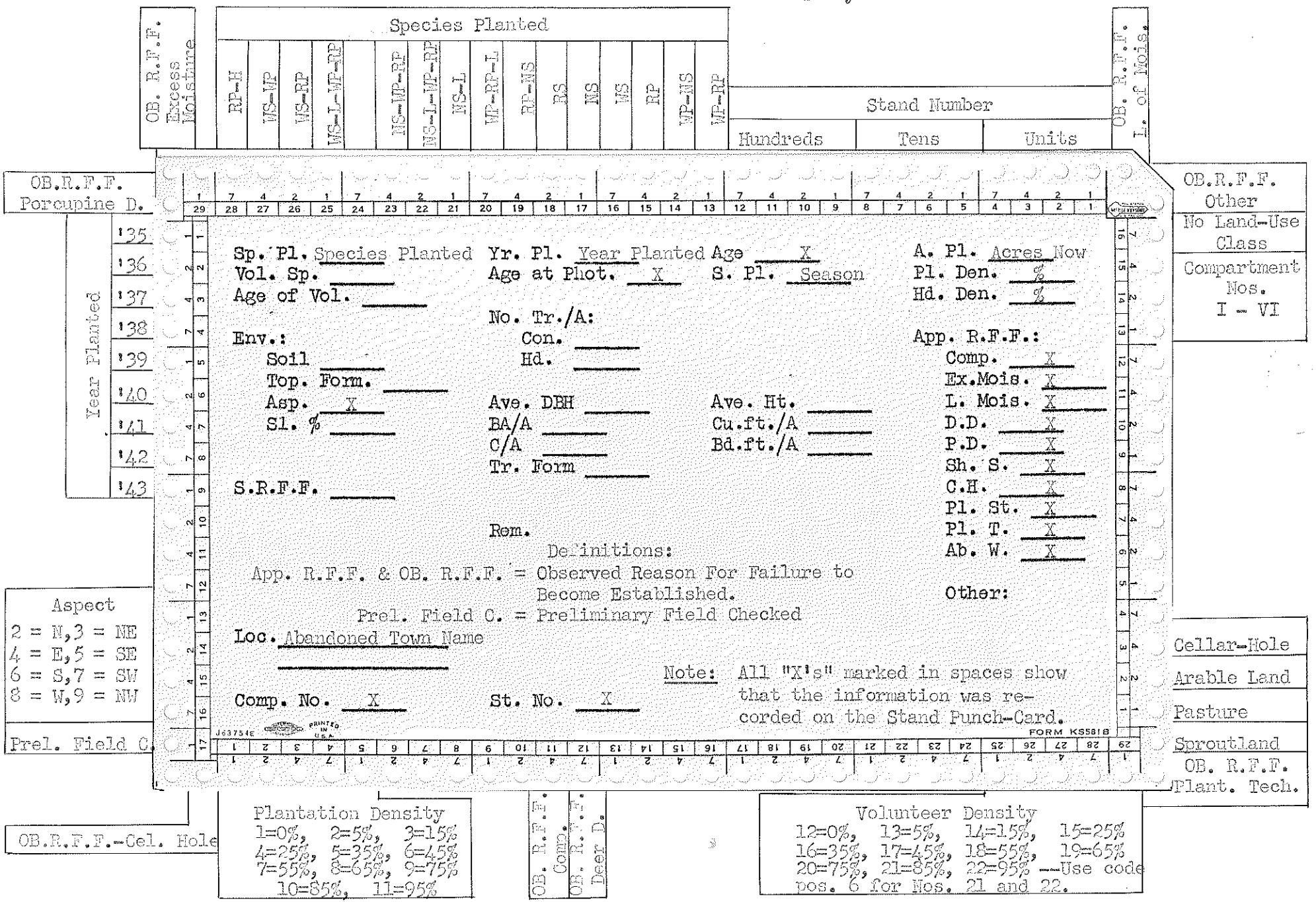
[1]Information received from Mr. Russell Snow, Forester, Quabbin Reservoir Watershed. 9/7/60.

FIGURE III.

Stand Data Utilized In This Study



Arable Land - land which had been used for growing agricultural crops such as vegetables for human consumption or forage for feeding domestic animals. This land showed evidence of intensive cultivation.

Pasture - land on which domestic animals were pastured, primarily open land and not pastured woodland.

Sproutland - land which had a dense growth of shrubby vegetation or deciduous and coniferous tree species of the seedling and sapling size. This was primarily land which had been retired from agricultural use in the recent past (1 - 15 years), not cut-over woodland.

The land-use classifications were transferred from the Metropolitan District Commission Re orestation Maps to Land-Use Base Maps, scale 1" = 20 chains, constructed from the base maps described on page 22 (see Figures I through VIII, Appendix A). From these maps, previous land-use was determined for each stand and this information was punched on each stand punch card. The percentage of establishment could then be determined for each land-use class by a standard sorting procedure.

The next step was to construct Acceptable Plantation Overlays (Figures A through H, Appendix A), in an attempt to relate crown closure classes to the definition of acceptable plantations presented by Zillgit and Rotty (1955), and discussed on page 9.

Patterns of fact relating acceptable plantations to previous land-use will be discussed in another section of this paper.

Field Work:

The field work was designed to supplement the photo interpretation of crown density and to investigate patterns of fact about site and other factors which might coincide with the various degrees of crown closure.

An 18 percent ground cruise was made of the study area to field check the photo interpretation. This cruise revealed that the estimation of per-

centage of crown closure was consistent. The only check which could be made of this was to compare different stands of the same density and judge if their appearance was the same on the ground. All stands encountered, which had been assigned the same percentage of establishment, appeared very similar on the ground.

This ground cruise also proved that deer damage, porcupine damage, competition from volunteer tree species, and excess moisture, as they affected plantation establishment, could be interpreted from the photos with a reasonable degree of accuracy.

Deer damage in this study, was restricted to the complete elimination of planted trees in deer yards and trails. These can be readily identified on the photos. Deer yards in the study area are always found in moist areas

Deer Yard on the Prescott Peninsula

Photo No. 1. This is stand No. 18, Compartment I, showing the typical appearance of a deer yard from the ground. Note the browse line on the pines and the fact that there is no woody vegetation other than established planted trees. Photo by Dodge, 6/60.

which are well protected from the wind. When viewed on the aerial photographs, they normally appear as a round to oval shaped openings in the plantation, located near an intermittant stream or swale, and when oval, the long axis of the yard parallels the drainage. Photo No. 1 shows a typical deer yard as seen on the ground. Deer runs, or trails, can sometimes be seen in younger plantations on the photos and these appear to be thin, meandering lines weaving through the plantation and usually cross roads at right angles through openings in walls or bar-ways.

Severe porcupine damage can be identified on aerial photographs as an opening in the plantation which is generally semi-circular in shape, or a series of semi-circular openings, located close to stone walls or old cellar-holes. The porcupine evidently girdles the tree closest to his den and when that dies, the next closest and so on, until he has killed a semi-cirdle of trees around his den. Photo Nos. 2 and 3 show typical porcupine damage to red pine.

Competition from deciduous trees is easily identified on aerial photographs by the much lighter tone of their wide, fluffy crowns. Conifers appear almost black and deciduous trees are grey to white in tone on the photos.

Excess moisture, in this study, is restricted to the identification of open water, swales, swamps, intermittent streams and brooks. Many swales and intermittent streams were planted because crews were instructed to plant any area in which they could walk.[1]

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[1]Information received from personal interview with Mr. Russell Snow, Forester, Quabbin Reservoir Watershed, July 1960.

Red Pines Killed by Porcupines

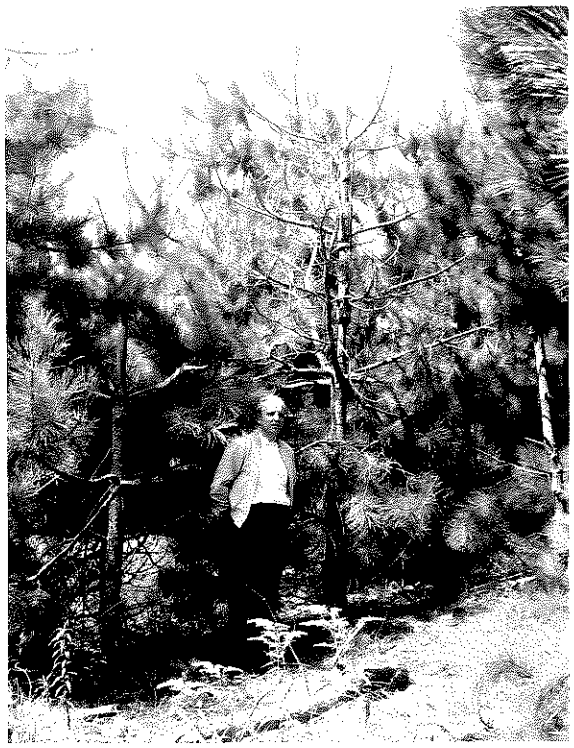


Photo No. 2. Typical porcupine damage to red pine in the study area. This damage was done to trees planted around an old cellar-hole and barn foundation. Photo by Dodge, 8/12/60.

Red Pine Girdled by Porcupine

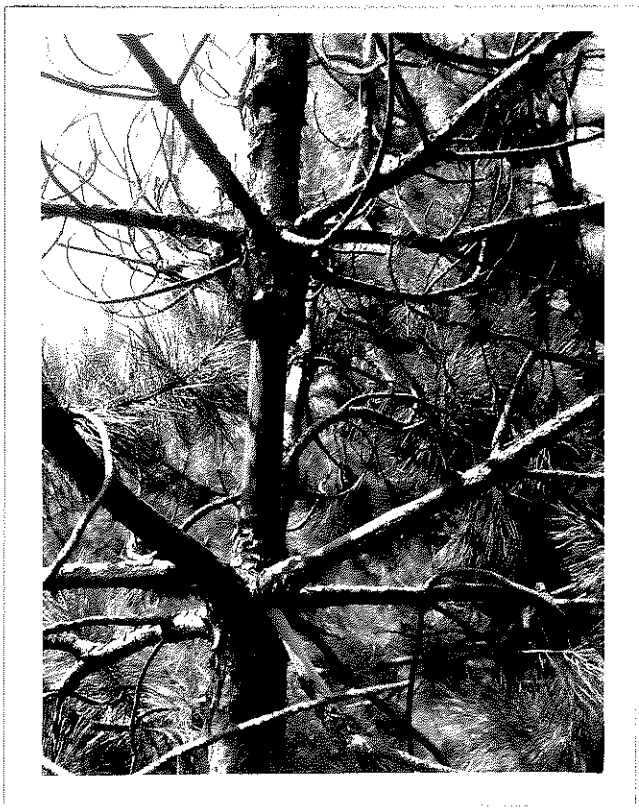


Photo No. 3. Typical appearance of girdle on red pine caused from feeding on the bark by porcupine. This tree still had some live branches below the girdle. This is the tree located to the right of the man in Photo No. 2. Photo by Dodge, 8/12/60.

A more detailed study of the entire area could not be undertaken during the time allotted this investigation. This author believes that the most practical method of studying the establishment processes in these plantations is through the case study method. Some case studies in the area might indicate trends of establishment that would not be shown in the photo interpretation and ground cruise. Studying the area by using the case study method required a partially subjective decision on the part of the investigator. The decision as to what constituted the major factor preventing establishment was apparent, but the areas chosen for detailed analysis as representative of this factor had to be subjectively selected.

The performance of stands with various percentages of crown closure could only be documented accurately if the condition of the area at the time of planting was known. The condition of the majority of the stands was generally known from the Land-Use Base Maps (Figures I through VIII, Appendix A). The condition of the land at the time of planting was further documented, on some areas, by ground photographs which were taken after the first growing season. The majority of these photographs were taken of what had been originally classified as arable land. There were, however, three areas photographed which represented two or more of the original land-use classes. These areas were selected as the case studies.

Twenty-fifth acre plots were evenly spaced across each case study area in an attempt to distribute them equally on each land-use class. Proportionately, the plots were not equally distributed because each case study area did not contain the same amount of acreage in each land-use class.

The following data were recorded on each twenty-fifth acre plot:

a. The number of planted trees and crown class of each tree. This information was used to compare stems per acre with percentage of crown density.

b. Age at eight foot intervals from ground level to crown tip of at least one planted tree in each crown class to determine the rate of height development.

c. A soil sample of each soil horizon, to 36 inches in depth, at plot center. This information was used to compare drainage classes and physical characteristics of the soil on the different land-use classes.

d. DBH, to the nearest inch, of each planted tree. This data was to be used for volume determinations but time did not permit.

e. Crown radius of at least one planted tree in each crown class. This information was not utilized in the present study.

f. Number of volunteer tree stems. This was used to compare stems per acre in various crown density classes.

g. Increment boring at four feet above ground level of at least one volunteer stem in each crown class. This data was compared with trees sectioned to find approximate age at the time of planting.

h. Height of at least one volunteer stem in each crown class. To be used to compare with heights of sectioned trees and height-over-age curves.

i. DBH of each volunteer stem. To be used for volume determinations but time did not permit.

j. The general conditions such as health, micro-flora, animal and insect damage, or other factors of interest were noted.

These data for each plot are listed in Appendix B.

One plot on each land-use class was mapped showing the position of each stem and the general crown coverage of the volunteer and planted species. These plots were selected because they were judged to be representative of the average conditions encountered on that particular area of land-use.

Two of the plots which contained a large number of volunteer species

were further examined. These plots were located in areas previously classified as sproutland. The plots were mapped for stem location and crown coverage and a total of 51 of the volunteers were felled and bucked into four foot bolts. Annual rings were counted at ground level and at the top of each bolt. This information was plotted on height-over-age curves, (Figures I through V, Appendix B), to give an indication of the rate of height development of these volunteers.

Photographs were taken showing the general appearance of each plot which was mapped. Photographs were also taken showing a view of each area from the same location as the original photographs taken of the plantations shortly after planting.

It was believed that this field work would produce information which could be used to relate previous land-use, deer damage, porcupine damage, competition and excess moisture to the varying percentages of crown density in the general study area.

TABLE NO. I

Number of Acres in Each Percent of Crown Closure Class by Compartments, and Acres and Percentage Distribution for all Compartments.

Percent of Crown Closure Class	Comp. I	Comp. II	Comp. III	Comp. IV	Comp. V	Comp. VI	All Compartments	
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Percent of Total Acres
0 %	179.5	242.2	225.7	131.5	121.5	249.3	1149.7	35.7
5 %	1.4	1.8	0.0	3.3	0.0	6.0	12.5	.3
15 %	6.4	4.8	4.4	11.0	0.0	1.9	28.5	.8
25 %	11.3	10.8	1.6	13.2	7.2	.5	44.6	1.4
35 %	3.8	90.7	9.8	.8	.2	5.8	111.1	3.4
45 %	0.0	8.2	4.2	2.6	0.0	11.9	26.9	.8
55 %	25.9	27.4	10.8	24.3	1.6	51.6	141.6	4.5
65 %	74.1	126.9	105.3	27.3	7.1	66.7	407.4	12.6
75 %	90.3	212.0	147.2	71.8	15.3	52.4	589.0	18.4
85 %	93.4	208.8	104.3	41.8	42.2	77.8	568.3	17.6
95 %	12.9	46.6	41.7	10.4	26.4	6.3	144.3	4.5
Totals	499.0	980.2	655.0	338.0	221.5	530.2	3223.9	100.0

DATA

Establishment:

A total of 3,223.9 acres of planted area was examined to determine the percentage of establishment. Table I shows the number of acres in each crown closure class by compartments, and acres and percentage distribution for all compartments.

Table I shows that 35.7 percent of the total acreage planted did not become established, 53.1 percent is from 55 to 95 percent established and only 6.7 percent is between 0 and 55 percent established. This data suggests that plantations either do not become established, or they tend to have a crown closure of 55 percent or more.

Previous Land-Use:

Eighty-two and two-tenths percent of the total acreage in the study area, 2,842.5 acres, was actually classified as to previous land-use by the Metropolitan District Commission.

The acreage found in each land-use class is as follows:

Arable land---------1,930.9 acres

Pasture---------416.7 acres

Sproutland---------466.1 acres

There were 28.8 acres in cellar-holes and 381.4 acres which were not classified. This acreage was not included in the investigation of the various adverse factors which influenced plantation establishment in this study area.

FIGURE NO. IV

Percent of Total Classified Acreage in Each Land-Use Class.

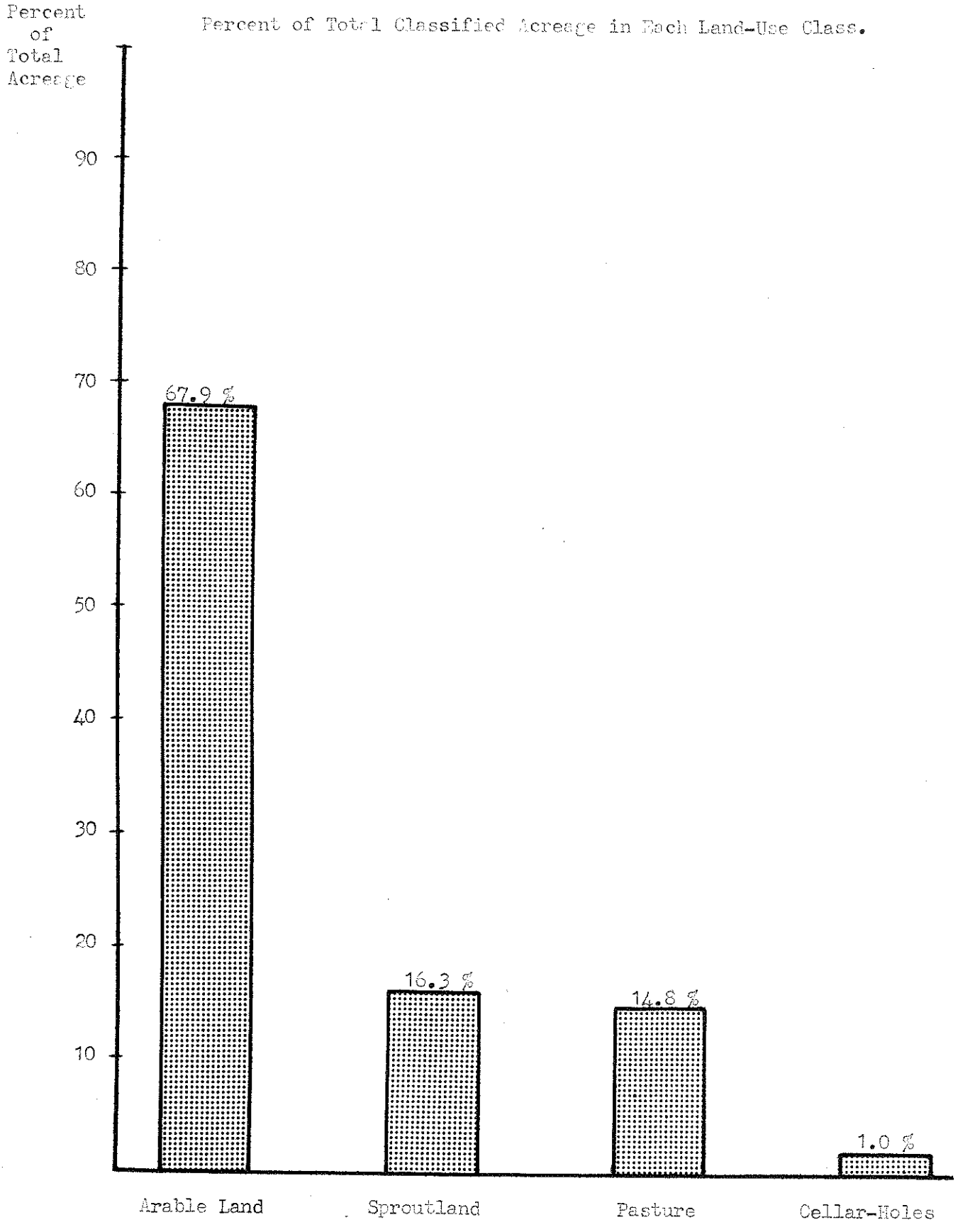


TABLE NO. II

Number of Acres and Percent of the Total Acreage
in Each Percentage of Crown Closure, by Land-Use Class.

Percent of Crown Closure	Arable Land		Pasture		Sproutland		Cellar-Holes	
	Acres	%	Acres	%	Acres	%	Acres	%
0 %	492.1	25.5	135.9	32.6	335.5	72.0	21.4	N/A [1]
5 %	5.6	.3	.4	.1	0.0	0.0	.5	N/A
15 %	13.7	.7	0.0	0.0	0.0	0.0	2.9	N/A
25 %	32.4	1.7	7.5	1.8	.2	.1	.8	N/A
35 %	65.0	3.4	17.4	4.2	12.0	2.6	1.1	N/A
45 %	11.7	.5	7.3	1.8	0.0	0.0	0.0	N/A
55 %	71.2	3.7	18.3	4.4	15.3	3.2	.4	N/A
65 %	223.9	11.6	85.8	20.6	41.4	8.9	0.0	N/A
75 %	436.7	22.6	70.1	16.8	37.4	8.0	1.3	N/A
85 %	452.1	23.4	66.0	15.8	19.7	4.2	.4	N/A
95 %	126.5	6.6	8.0	1.9	4.6	1.0	0.0	N/A
Totals	1930.9	100.0	416.7	100.0	466.1	100.0	28.8	N/A

[1]Not Applicable.

Figure IV shows graphically the percentage of the classified acreage found in each type of previous land-use.

Table No. II lists the number of acres, and the percent of total acreage in each percentage of crown closure, found on each of the land-use classes. The number of acres covered by the effective area of old cellar-holes is also listed.

This table shows that the arable land has the greatest percentage of acreage in the five highest crown closure classes and sproutland has the most acreage with no planted trees in the canopy. Pasture paralleled the percentage of establishment on arable land; however, it should be noted that pasture had 7.1 percent more area with no planted trees in the canopy and less acreage in the three highest crown closure classes. This table also shows that the land classified as to land-use within the study area has even less acreage with 5 to 55 percent crown closure than that of the general study area.

Figure No. V illustrates the relative amounts of acreage found in the different crown closure classes on arable land, pasture, and sproutland.

Adverse Factors Affecting Establishment, or Crown Closure:

The adverse factors which were investigated by aerial photo interpretation and field investigation were described on pages 23 through 26, for the purposes of tabulation, deer and porcupine damage were combined. Also, the areas on which competition, excess moisture or animal damage could not be related to percentage of establishment were grouped under a category termed "Other".

Tables III, IV and V illustrate the degree to which each adverse

FIGURE NO. V

Cumulative Graph Showing the Relative Amounts of Acreage Found in Each Crown Closure Class on Arable Land, Pasture and Sproutland.

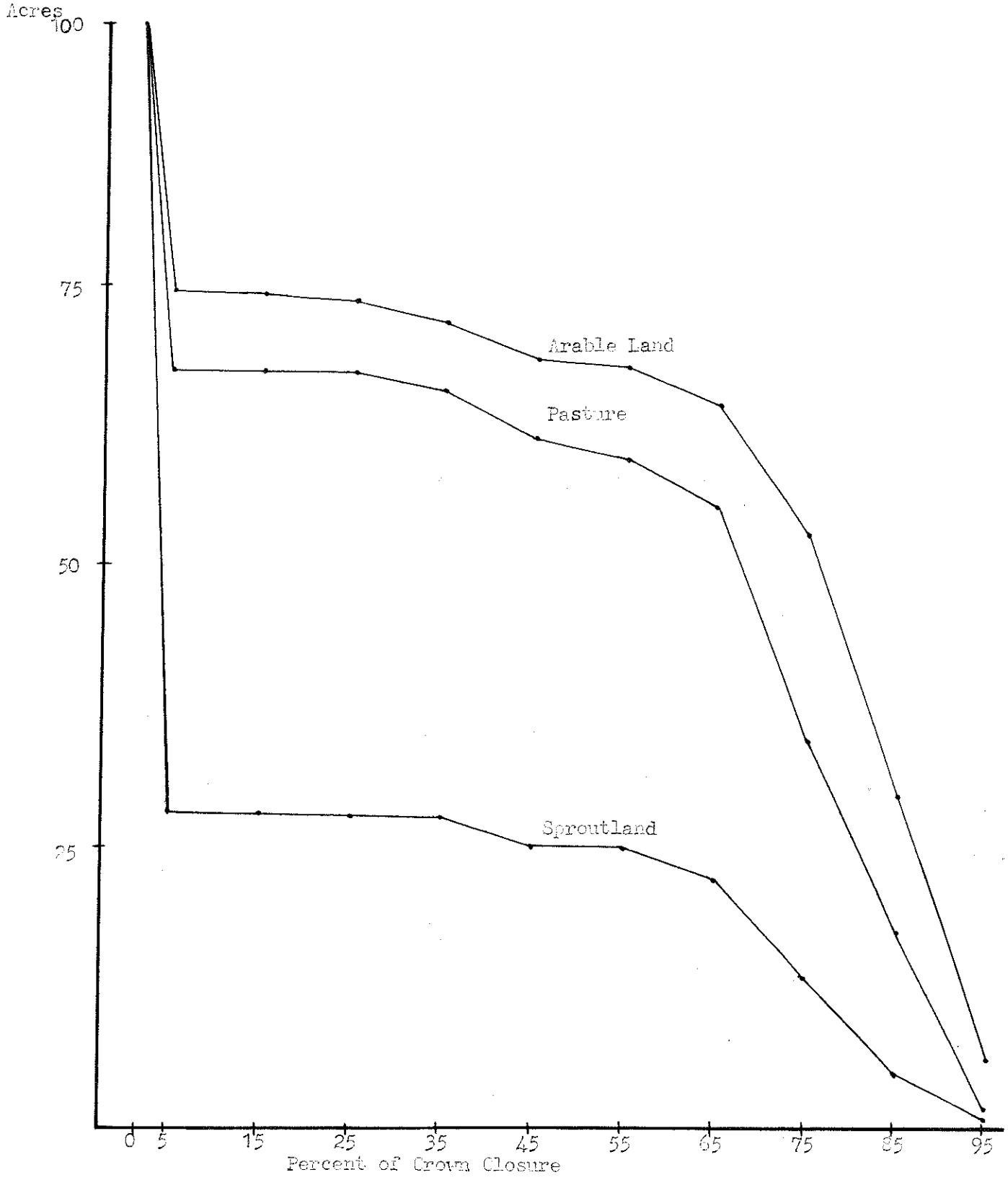


TABLE NO. III

Distribution of the Acreage in Plantations on Arable Land, Among Crown Closure Classes, by Estimated Primary Factor Limiting Establishment.

Percent of Crown Closure, or Establishment	Competition		Excess Moisture		Animal Damage		Other		Total Arable Land[1]
	Acres	%	Acres	%	Acres	%	Acres	%	
0 %	360.6	73.3	95.1	19.3	11.2	2.3	25.2	5.1	492.1
5 %	0.0	0.0	1.6	28.6	4.0	71.4	0.0	0.0	5.6
15 %	1.6	11.7	0.0	0.0	6.4	46.7	5.7	41.6	13.7
25 %	13.4	41.4	1.6	4.9	1.7	5.2	15.7	48.5	32.4
35 %	22.2	34.2	0.0	0.0	.3	.4	42.5	65.4	65.0
45 %	7.5	64.1	0.0	0.0	0.0	0.0	4.2	35.9	11.7
55 %	15.3	21.5	4.0	5.6	2.4	3.4	49.5	69.5	71.2
65 %	111.1	49.6	35.1	15.7	30.5	13.6	47.2	21.1	223.9
75 %	196.0	44.9	126.5	29.0	103.3	23.7	10.9	2.4	436.7
85 %	290.0	64.2	61.6	13.6	96.0	21.2	4.5	1.0	452.1
95 %	84.5	66.8	14.2	11.2	27.8	22.0	0.0	0.0	126.5
Totals	1102.2	57.1	339.7	17.6	283.6	14.7	205.4	10.6	1930.9

[1]In each crown closure class.

TABLE NO. IV

Distribution of the Acreage in Plantations on Pasture, Among Crown Closure Classes, by Estimated Primary Factor Limiting Establishment.

Percent of Crown Closure, or Establishment	Competition		Excess Moisture		Animal Damage		Other		Total Pasture[1]
	Acres	%	Acres	%	Acres	%	Acres	%	
0 %	106.2	78.1	14.6	10.7	7.2	5.4	7.9	5.8	135.9
5 %	0.0	0.0	0.0	0.0	.4	100.0	0.0	0.0	.4
15 %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 %	6.6	88.0	0.0	0.0	0.0	0.0	.9	12.0	7.5
35 %	13.8	79.3	3.6	20.7	0.0	0.0	0.0	0.0	17.4
45 %	7.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3
55 %	16.7	91.3	0.0	0.0	0.0	0.0	1.6	8.7	18.3
65 %	84.0	98.7	1.8	1.3	0.0	0.0	0.0	0.0	85.8
75 %	21.9	31.2	1.3	1.9	46.9	66.9	0.0	0.0	70.1
85 %	48.9	74.1	2.8	4.2	10.3	15.6	4.0	6.1	66.0
95 %	6.2	77.5	.4	5.0	1.4	17.5	0.0	0.0	8.0
Totals	311.6	74.8	24.5	5.9	66.2	15.9	14.4	3.4	416.7

[1] In each crown closure class.

TABLE NO. V

Distribution of the Acreage in Plantations on Sproutland, Among Crown Classes, by Estimated Primary Factor Limiting Establishment.

Percent of Crown Closure, or Establishment	Competition		Excess Moisture		Animal Damage		Other		Total Sproutland[1]
	Acres	%	Acres	%	Acres	%	Acres	%	
0 %	289.8	86.4	39.3	11.7	.5	.2	5.9	1.7	335.5
5 %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 %	0.0	0.0	0.0	0.0	0.0	0.0	.2	100.0	.2
35 %	0.0	0.0	.1	.8	0.0	0.0	11.9	99.2	12.0
45 %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55 %	11.4	74.5	0.0	0.0	0.0	0.0	3.9	25.5	15.3
65 %	28.5	68.8	0.0	0.0	8.8	21.3	4.1	9.9	41.4
75 %	31.2	83.4	2.1	5.6	4.1	11.0	0.0	0.0	37.4
85 %	12.3	62.4	0.0	0.0	7.4	37.6	0.0	0.0	19.7
95 %	3.6	78.3	1.0	21.7	0.0	0.0	0.0	0.0	4.6
Totals	376.8	80.8	42.5	9.1	20.8	4.5	26.0	5.6	466.1

[1] In each crown closure class.

factor investigated affected crown closure in terms of acres, and percent of total acreage, within each crown closure class. These tables also show the extent to which each adverse factor was involved in all percentages of crown closure on the three types of previous land-use.

If all crown closure classes are combined on the three types of land-use; competition was judged to be the primary limiting factor on 63 percent of the acreage, excess moisture on 14.3 percent, animal damage on 13.1 percent and other factors on 8.6 percent. The cellar-holes, which were not included in the investigation, equal one percent of the total area classified as to land-use.

Figures VI and VII show how much of the area was influenced by competition in each crown closure class on each type of land-use. This figure also illustrates the relative amount of acreage in each percentage of crown closure on all three types of land-use.

Case Studies:

The following case studies were developed from an intensive study of sample plots in the field. They illustrate the impact that competition from volunteer growth had on the planted trees and explain some aspects of the processes involved.

FIGURE NO. VI

The Impact of Competition and Other Factors Upon the Percentages of Crown Closure on Arable Land and Pasture.

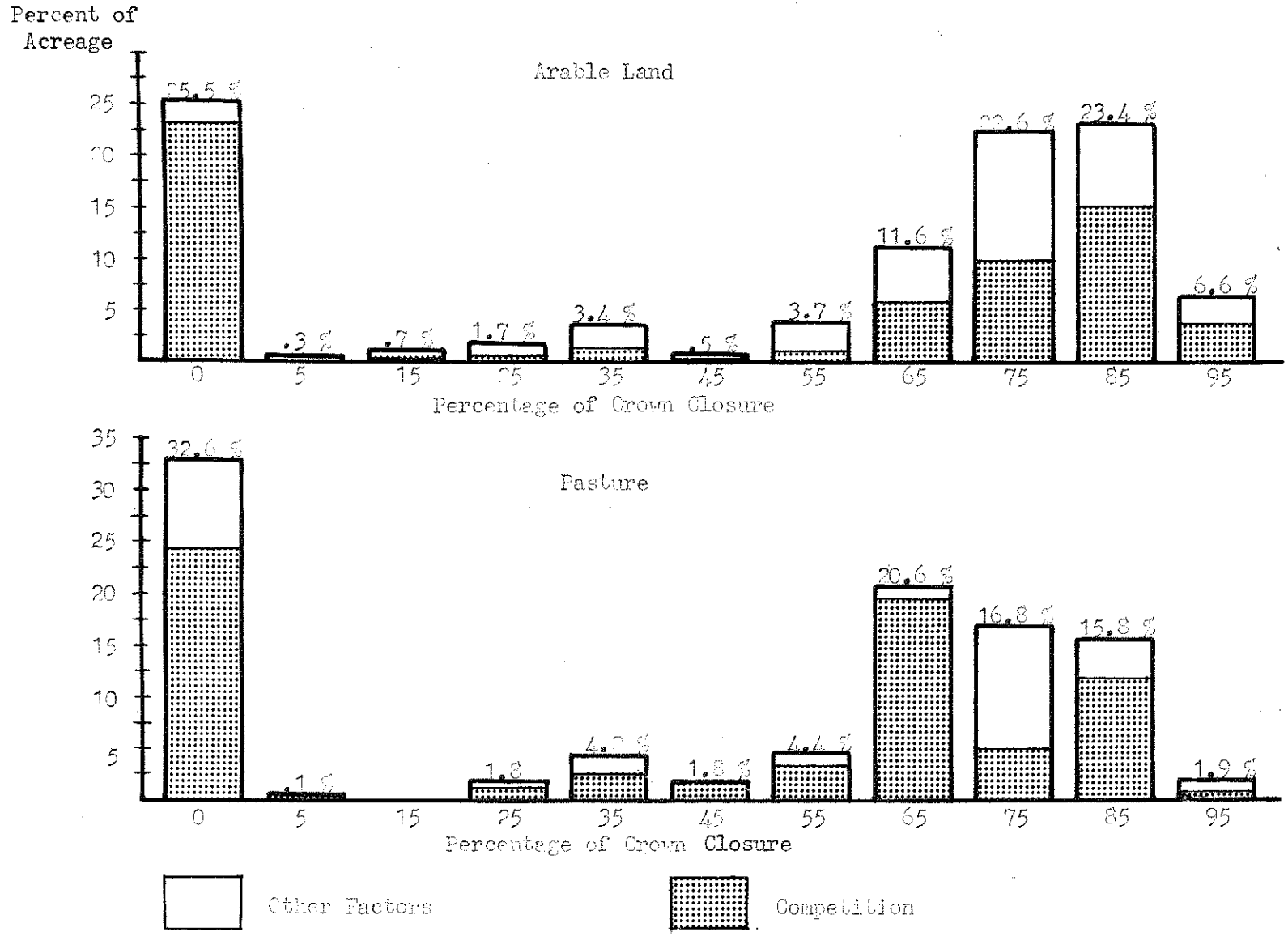
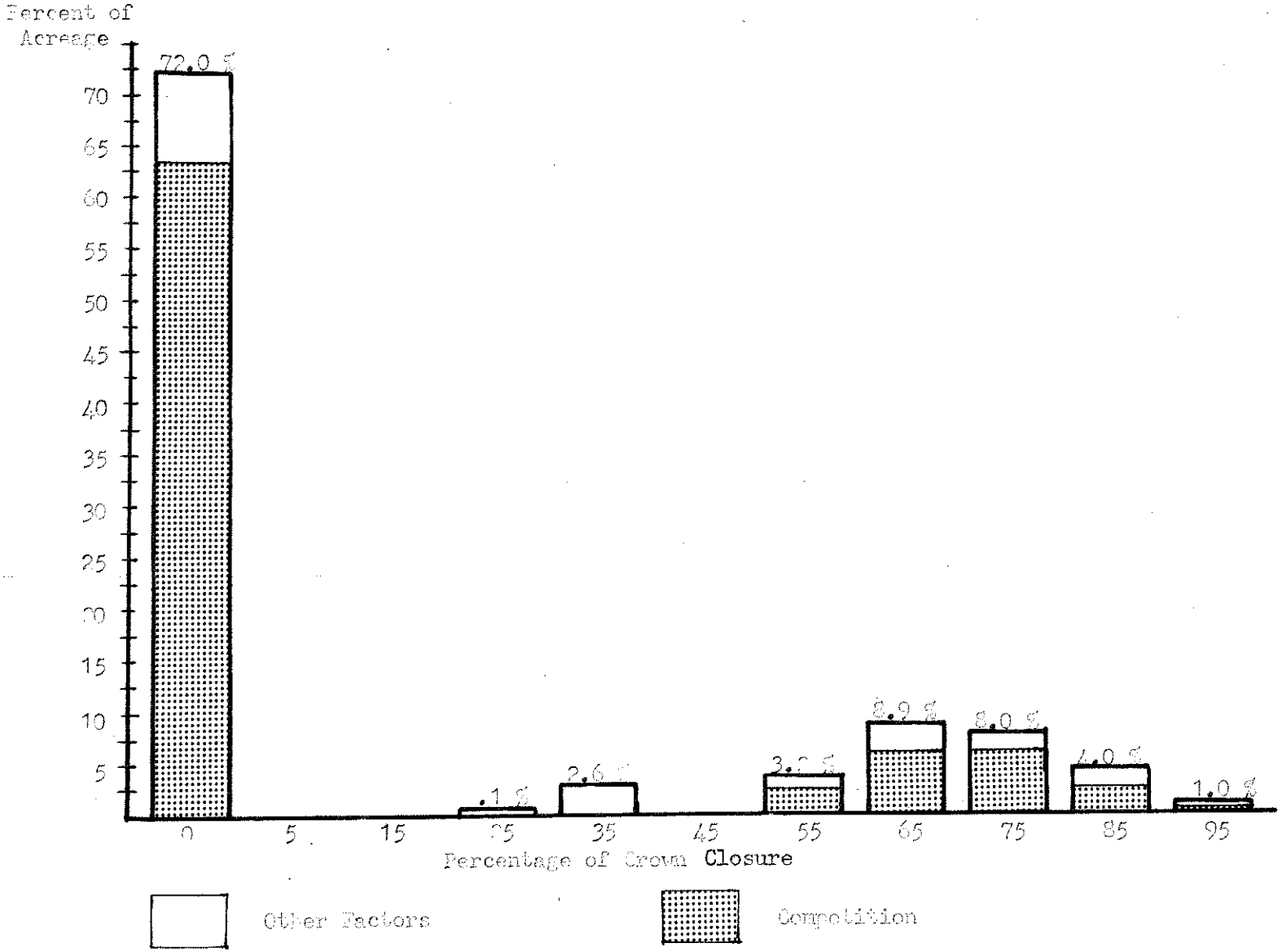
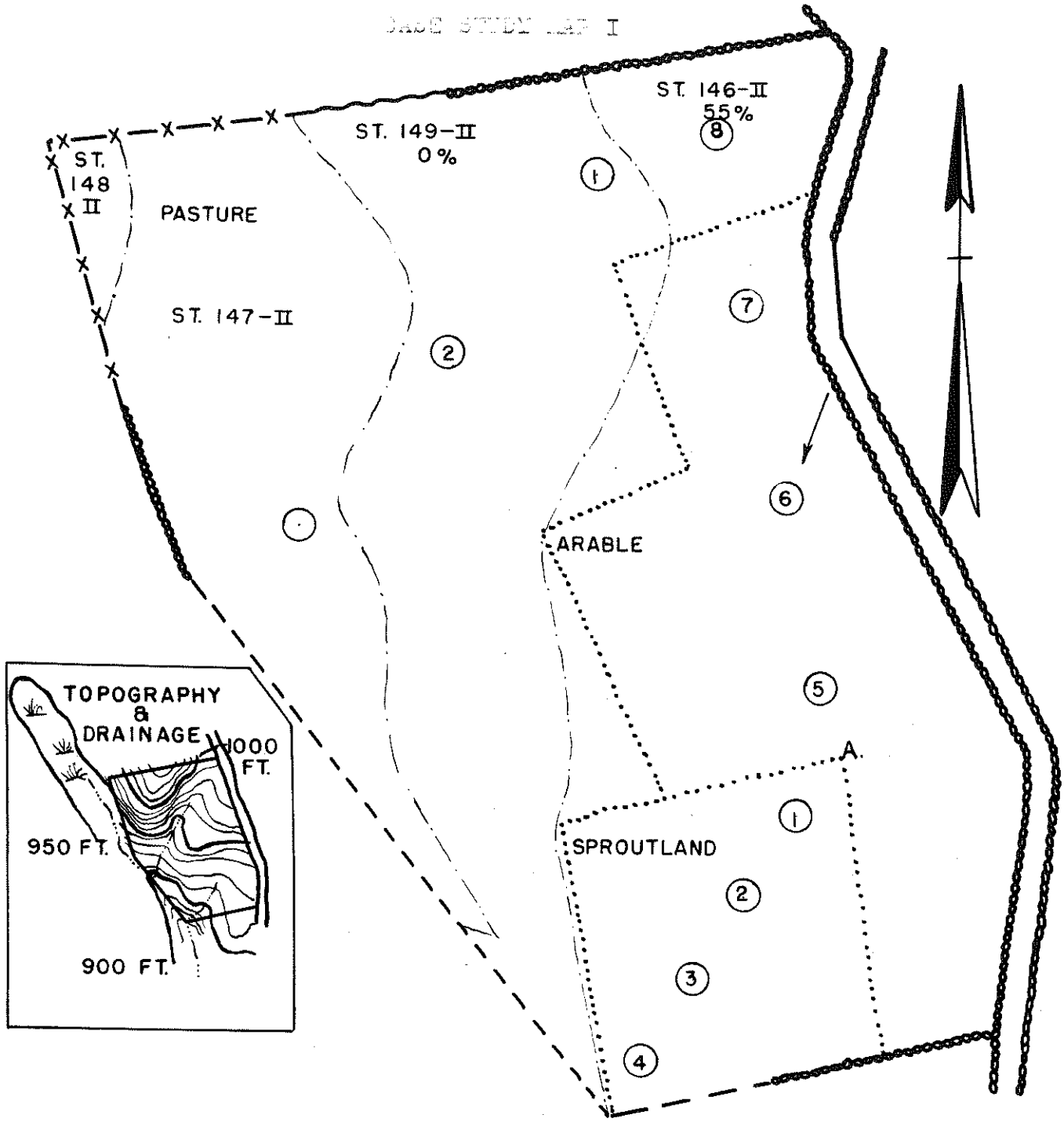


FIGURE NO. VII

The Impact of Competition and Other Factors Upon the Percentages of Crown Closure on Sproutland.



CASE STUDY AREA I



L E G E N D

CASE STUDY AREA I

Scale: 1" = 200 feet

- — Land Classification Boundary
- (2) — Plot Location and Number
- — Stand Boundary
- — Location and Direction from Which Ground Photos Were Taken
- A — Point Located on Early Ground Photos

Stands 147-II and 148-II not included in this study.

CASE STUDY AREA I

Stands 146 and 149, Compartment II.

Land-Use Classification:

The study area includes a total of 23.3 acres classified as; arable - 8.5 acres, pasture - 7.7 acres, and sproutland - 4.1 acres. This study area was used because it is included in field photographs showing the general condition of the area in 1936, 1939, and 1941 (see MDC photos 2015, 2465, and 2591).

Soils and Site:

Arable land - soil is a well-drained Charlton fine sandy loam. This area has a southwest to west aspect and is located on the upper and middle sections of a long slope (300'+) of 0 to 10 percent grade. Topographic elevation ranges from 920 to 1000 feet above sea level.

Pasture - soils are moderately well-drained Sutton fine sandy loam and poorly-drained Leicester very stony loam. This area has a southwest to west aspect and is located on the lower and bottom sections of a long slope of 0 to 10 percent grade. Topographic elevation ranges from 950 to 1030 feet above sea level.

Sproutland - soils are poorly-drained Leicester very stony loam and moderately well-drained Scituate fine sandy loam. The Scituate fine sandy loam is localized in an area which is about 400 feet long and 50 feet wide and is located at the south end of the sproutland. The total area of sproutland has a southwest aspect and is located on the lower section of

a long slope of 0 to 5 percent grade. Topographic elevation is from 870 to 920 feet above sea level.

Planting:

The entire study area was planted in the spring of 1936 with Norway spruce 3-2 and 3-3 transplant stock purchased from the Pennsylvania State Nursery. The areas which failed to survive were replanted in the spring of 1938 with European larch 2-0 seedling stock from the Quabbin Reservoir Watershed nurseries. A 5' x 5' spacing was used throughout.

Initial Survival:

Initial survival was estimated by Snow (1941) at about 30 to 40 percent. The high percentage of mortality was attributed to the fact that many trees were in very poor condition when received from the nursery. They had overheated in the express car during shipment and many trees were found dead when unpacked from the crates. The trees which were planted either died or were stunted and grew slowly (Snow, 1941).

The European larch which was used to replace the dead spruce had initially survived in good condition (Snow, 1941).

Animal Damage:

Snow (1941) reported that damage had been done in the areas planted with Norway spruce and European larch by deer, rabbits and rodents. This damage included browsing of the tops and eating the bark.

General Condition of the Plantations During The First Six Growing Seasons.

Arable Land:

An examination of MDC photos; 2015, 2465, and 2591 show that survival was not exceptionally high on the arable land. As previously reported,

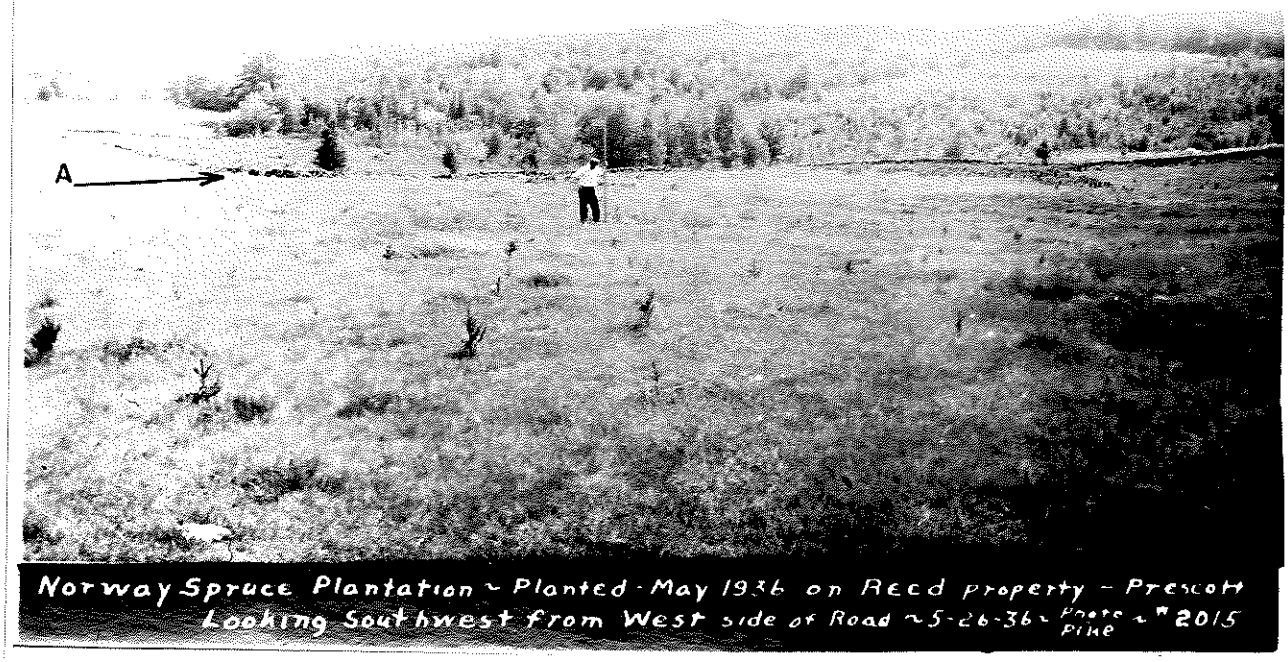
this was due to the poor condition of the planting stock. The competition from herbacious perennials and grass did not appear to have an adverse effect on the spruce. European larch cannot be identified in the photographs, probably because the needles were off at the time the photos were taken. This author suspects that European larch was in the minority even at this early age due to the animal damage previously noted. Also, the present study of the area shows that European larch is practically lacking, and that which exists is seriously deformed from porcupine damage (see photo No. 2). The Norway spruce shown in the MDC photographs appears to have grown well and was relatively healthy at the end of the sixth growing season.

Sproutland:

A dissection of the volunteers on Plot No. 1, in the sproutland, indicates that these trees were from two to eight years of age at the time the spruce were planted (Table I, Appendix B). Fifteen volunteers (375 per acre) existed at the time the spruce was planted, and they ranged from three to nine feet in height (Table I, Appendix B). The same table shows that three volunteers (75 per acre) seeded into this area during the year that spruce were planted. It is probable that red maple predominated on the sproutland at the time of planting. Photographs of the area taken at that time sho w that there was a much denser growth of vegetation in the sproutland than on the arable land.

By the end of the sixth growing season the spruce had reached an average height of five feet (Figure I, Appendix B), and the volunteers ranged from nine to fifteen feet in height (Figure II, Appendix B). Probably all

Case Study Area I at the Time of Planting.



MDC Photo 2015. Arable land - foreground, pasture - right center, sproutland - left center behind point "A". See Case Study Map I.

Case Study Area I Three Years After Planting.

MDC Photo 2465. Same view as MDC Photo 2015.

Case Study Area I Five Years After Planting.

MDC Photo 2591. Same view as MDC Photos 2015 and 2465.

Case Study Area I Twenty-four Years After Planting.

Photo No. 4. Taken from the same place and looking in the same direction as MDC photos. The man is standing on a rise of ground approximately ten feet above the base of the trees. Photo by Dodge, 4/12/60.

of the planted trees which had survived in the sproutland were in the understory six years after planting.

Pasture:

Photos taken at the time of planting show that the area classified as pasture seemed to have some open area comparable to arable land and some which was similar to the sproutland (MDC Photo 2015). Judging from a study of plots in the pasture land, the volunteer species in this area were probably in the same age class as those in the sproutland. By the end of the sixth growing season, spruce could be seen growing in the openings but none could be seen in the brushy areas (MDC Photo 2591).

General Condition of the Plantations at the Twenty-fourth Growing Season.

Arable and sproutland are located in stand No. 146-II and the pasture is located in stand No. 149-II. Detailed descriptions of each plot in the three land classifications are found in Appendix B, under Field Notes. The general condition on the three land classifications is as follows:

Arable Land:

The areble land supports an average of 419 planted trees per acre, of which 375 are in the dominant and co-dominant crown class. European larch average 25 trees per acre, but only one-fourth of these would be in the dominant or co-dominant crown class (Tables IV & V, Appendix B). The range in number of planted trees per acre is from 200 to 675. Porcupine damage has been severe in the larch and the result has been that this species is a minor element in the stand. Photo No. 5 shows the type of deformity resulting from porcupine damage to the larch in this plantation.

The Norway spruce, on the other hand, have grown up in fairly dense groups with openings between the groups. The average height of the stand is 37 feet and the average DBH is 6.8 inches (Tables IV & V, Appendix B). Figure No. VIII shows the general stem and crown distribution of trees on Plot No. 7 and Photo No. 6 is a view looking northwest across the plot. This plot is quite typical of the entire stand. In the area where the planted trees failed to become established, there is no woody vegetation. Various grasses, milkweed, goldenrod, and scattered grapevines dominate these areas. Deer browsing has probably kept deciduous competition from invading the areas which did not become established with planted trees. Photo No. 7 illustrates this situation. The only areas in this stand where deciduous competition exists are along stone walls and roadside, and this vegetation predates the planting.

Porcupine Damage to European Larch.

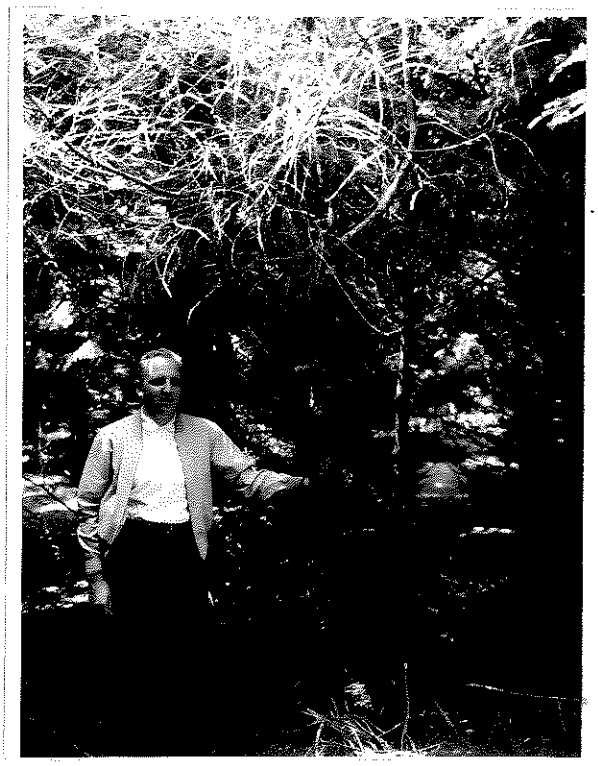
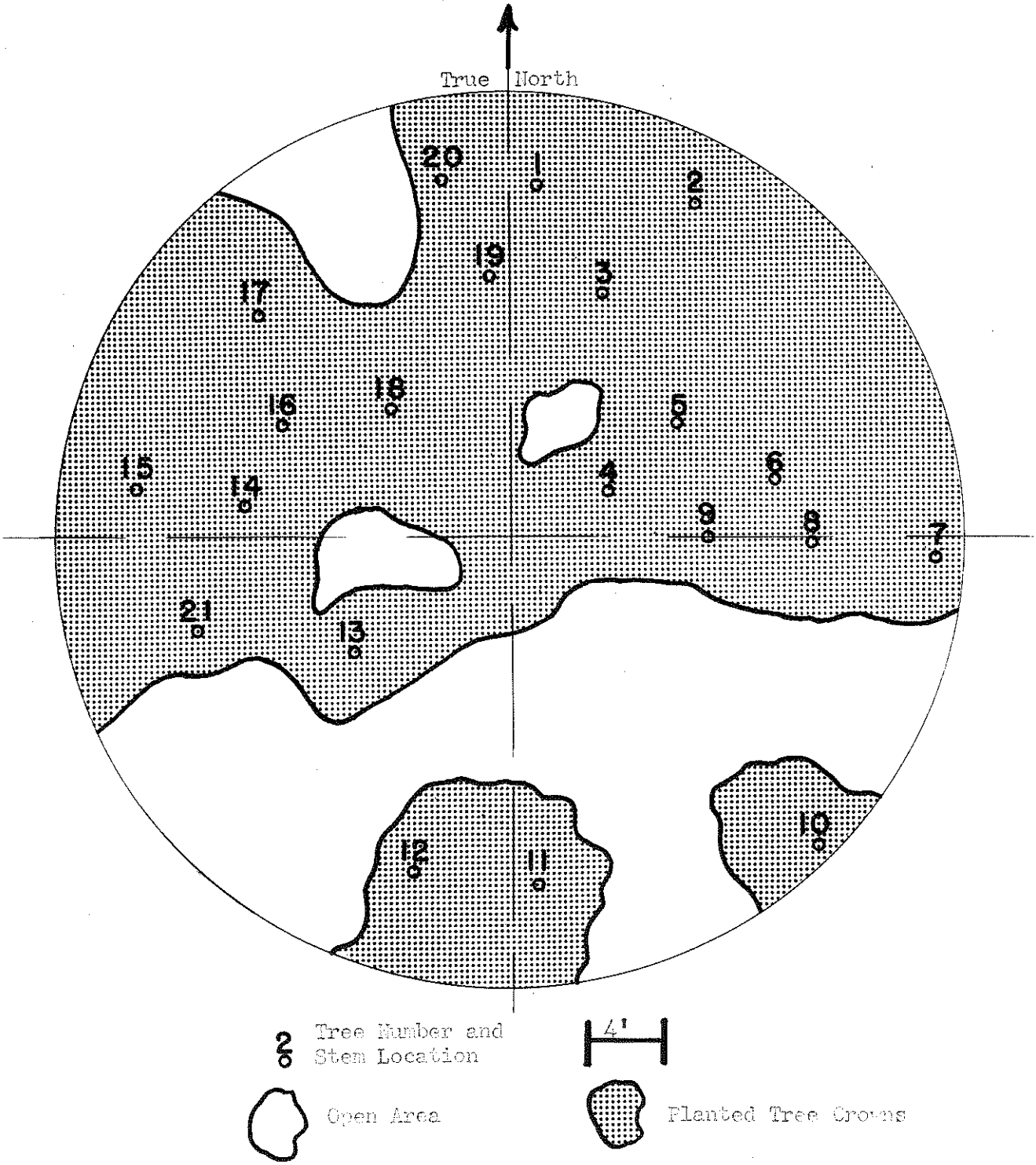


Photo No. 5. Typical example of porcupine damage to European larch. Note two deformations before the tree reached a height of ten feet. Photo by Dodge, 8/12/60.

FIGURE NO. VIII

Map of Stem and Crown Distribution on
Plot No. 7, Stand 146 - II.



Group of Norway Spruce Twenty-four Years After Planting.

Photo No. 6. Typical group of Norway spruce in Plot No. 7. Tree No. 18 is in the center of the photo and tree No. 4 is in the right foreground. Trees which are not crowded have attained the largest DBH. Tree No. 4 has 9" DBH. See Figure VIII for location. Photo by Dodge, 6/9/60.

Opening Between Groups of Norway Spruce.

Photo No. 7. Area where no planted trees became established. Note only herbacious vegetation. These areas range from 10 to 40 feet in width and from 10 to 60 feet in length. Photo by Dodge, 8/12/60.

Sproutland:

This area supports two distinct types of woody vegetation. One type is represented by Plot No. 4, stand 146-II, which is located in the Scituate fine sandy loam described previously. This particular area supports a dense growth of low-bush blueberry, bayberry, and sweetfern, one to three feet tall. Vegetation of this type can be found on approximately one-half acre in the southern end of the sproutland.

The other type of woody vegetation found in this area is made up of groups of tree species such as those found on Plots No. 1 and 2, stand 146-II. Red maple predominates but white ash, pin cherry, gray birch and common alder are also present. These two plots are both located on Leicester very stony loam.

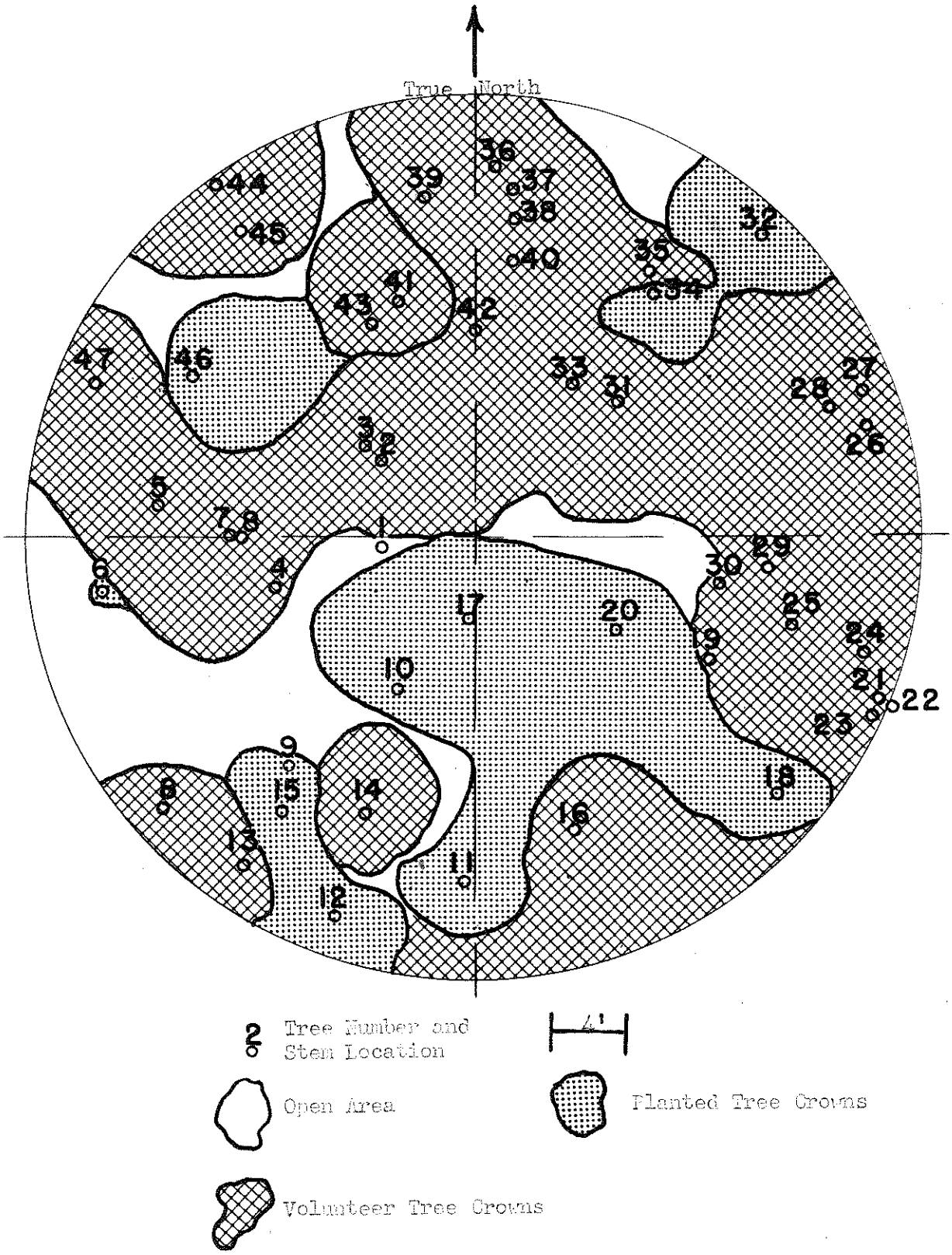
The author believes that it is very probable that the conditions described above will exist on any of the areas described as sproutland under the MDC land-use classification and, therefore, Plot 4 has been included as a sample plot for use in this case study.

The sproutland supports an average of 208 planted trees per acre, of which 63 are in the dominant and co-dominant crown class. The range of planted trees per acre is from 0 to 625. This area also supports an average of 500 volunteer trees per acre, of which 363 are in the dominant and co-dominant crown class. The number of volunteer stems per acre ranges from 0 to 650.

Trees planted in the sproutland became established in groups, evidently only where there was no volunteer woody vegetation to compete with them. There is an average of 17 European larch per acre, one-half of these are in

FIGURE NO. IX

Map of Stem and Crown Distribution on
Plot No. 1, Stand 146 - II.



the dominant and co-dominant crown class. Porcupine damage to larch is much less severe in the sproutland. The average height of the planted trees is 26 feet and the average DBH is 4.3 inches (Table II, Appendix B). The volunteer tree species average 37 feet in height and 3.9 inches in DBH (Tables I & III, Appendix B). Figure No. IX shows the general distribution of stems and crowns on Plot 1, stand 146-II. This is judged to be typical of the area where planted trees became established in sproutland. Photo No. 8 is a view of Plot No. 2, stand 146-II, looking northeast, and is judged to be typical of areas where volunteer species predominate.

Sproutland Twenty-four Years After Planting.

Photo No. 8, looking northeast across Plot No. 2, stand No. 146-II. Note that there is a minimum of woody vegetation below a height of six feet. Deer browsing eliminates all reproduction. These volunteers are from 23 to 32 years of age. Photo by Dodge, 8/12/60.

Pasture:

Pasture supports an average of 150 planted trees per acre, of which 125 trees are in the dominant and co-dominant crown class. The range of planted trees per acre is from 150 to 550. The pasture also supports an

average of 363 volunteer trees per acre, of which 275 are in the dominant and co-dominant crown class. The range of volunteer trees is from 75 to 650 stems per acre. Planted trees became established in groups in the areas which contained no volunteer species or shrubby vegetation to compete with them. No European larch are growing in this area. The average height of the planted trees is 28 feet and the average DBH is 4.3 inches (Table VI, Appendix B). Volunteer species average 37 feet in height and 5.2 inches DBH (Table VII, Appendix B). Figure No. X shows the general distribution and crown coverage in Plot No. 1, stand 149-II. This is judged to be typical of any area where planted trees became established in pasture. Photo No. 8 is typical of stands where volunteer species predominate in pasture.

Summary of Observations on Case Study Area I.

There is some question as to the advisability of using this study area as a case study because of the low initial survival. This investigator believes that the three areas of different land-use were planted with the same quality of planting stock and initial survival was approximately the same in all areas. Any differences in plantation establishment on these areas should, therefore, be due to something other than initial survival.

One measure of tree growth is the height trees attain at any given age. Plotting the height growth of Norway spruce on this study area against the height growth of volunteer tree species on all study areas shows that the average height growth of Norway spruce will not reach that of the volunteers until approximately 24 years after planting (Figure XI-A). Plotting the average height growth of underplanted spruce on this study area against the average height growth of volunteer species shows that underplanted Norway spruce probably will not attain a height equal to that of

FIGURE NO. XI - A

Relation of Total Height to Age of Planted Norway Spruce and Deciduous Volunteer Tree Species on the Prescott Penninsula, Quabbin Reservoir Watershed. Taken From Plot Measurements (Figures I & II, Appendix B).

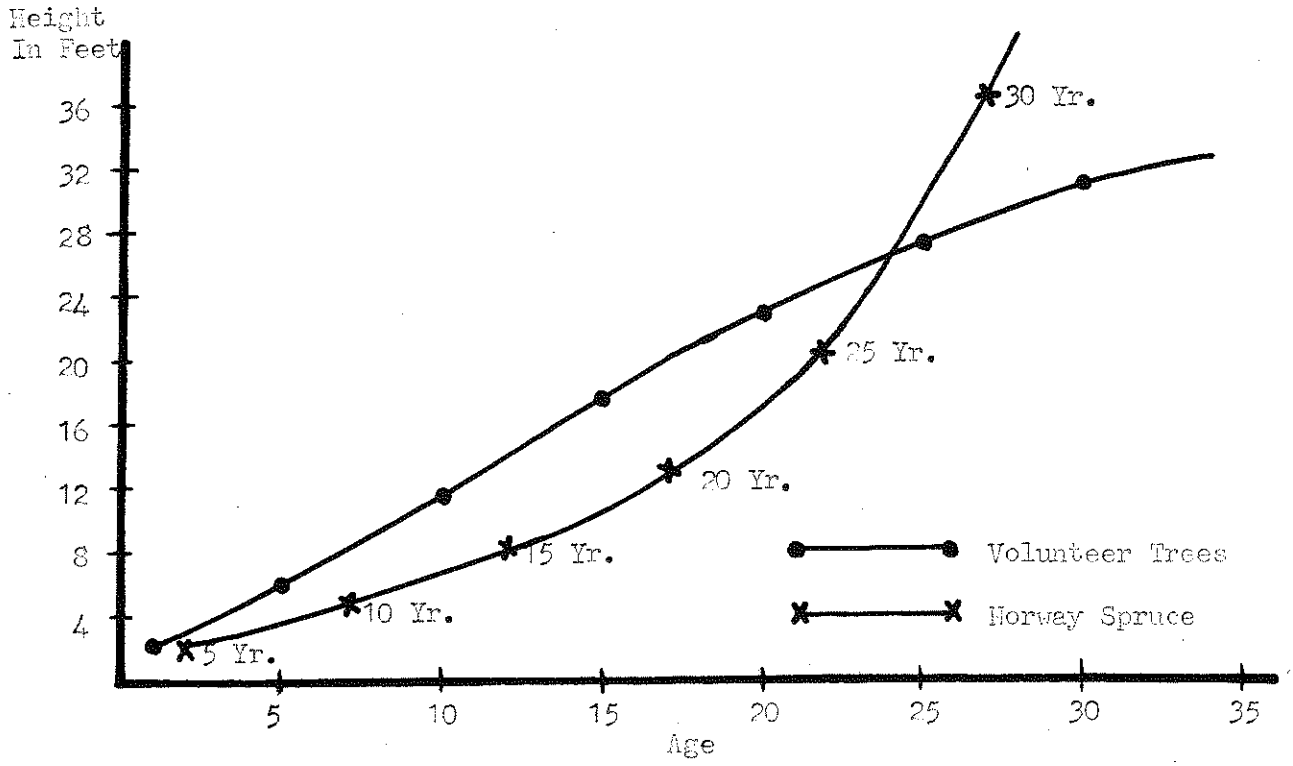
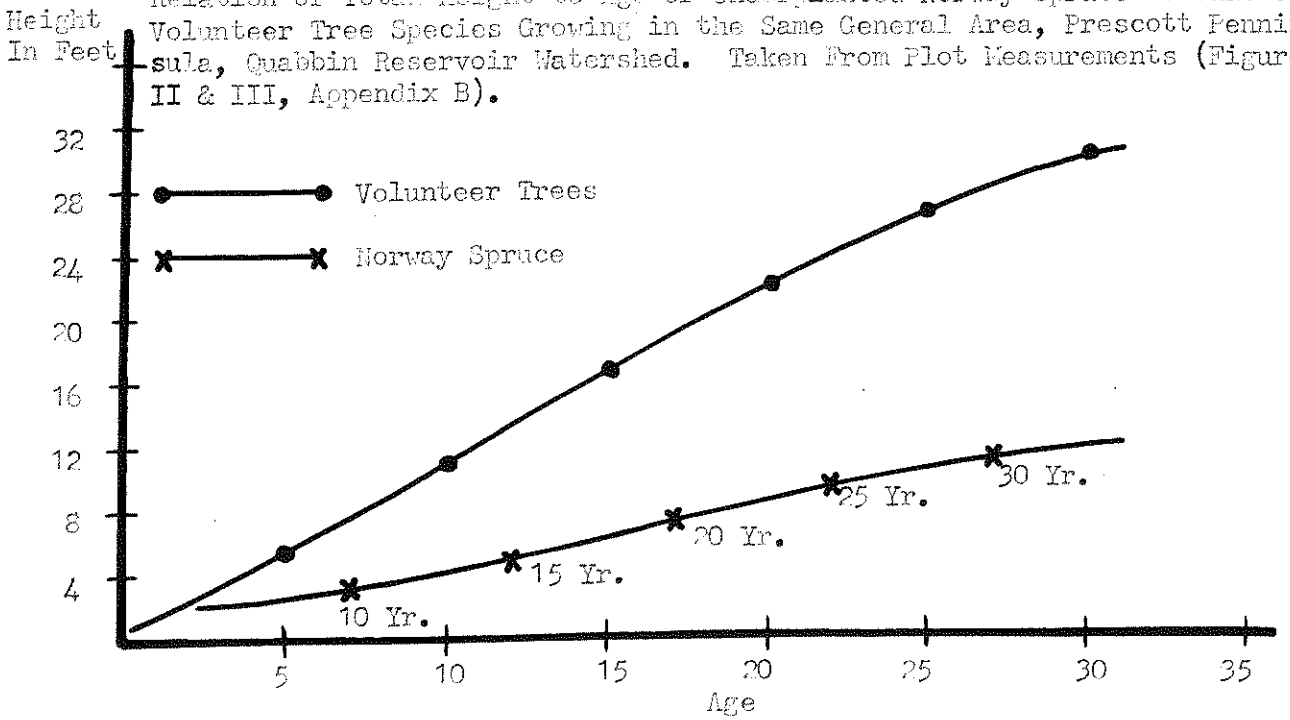


FIGURE NO. XI - B

Relation of Total Height to Age of Underplanted Norway Spruce to that of Volunteer Tree Species Growing in the Same General Area, Prescott Peninsula, Quabbin Reservoir Watershed. Taken From Plot Measurements (Figures II & III, Appendix B).



the volunteers (Figure XI-B). Comparison of Figures XI-A and XI-B indicate that Norway spruce probably will not become established where it has to compete with volunteer tree species which exist at the time of planting.

Observations and data recorded in this study area further indicate that Norway spruce became established most readily in areas where competition from deciduous species was at a minimum. Planted trees became established in groups on all three land-use classifications. These groups were larger and contained more trees in the arable land and pasture than in sproutland (Figures VIII, IX & X). Stand Table No. 1 shows the average number of planted and volunteer trees per acre in each land-use area and the average number of trees in the dominant and co-dominant crown class.

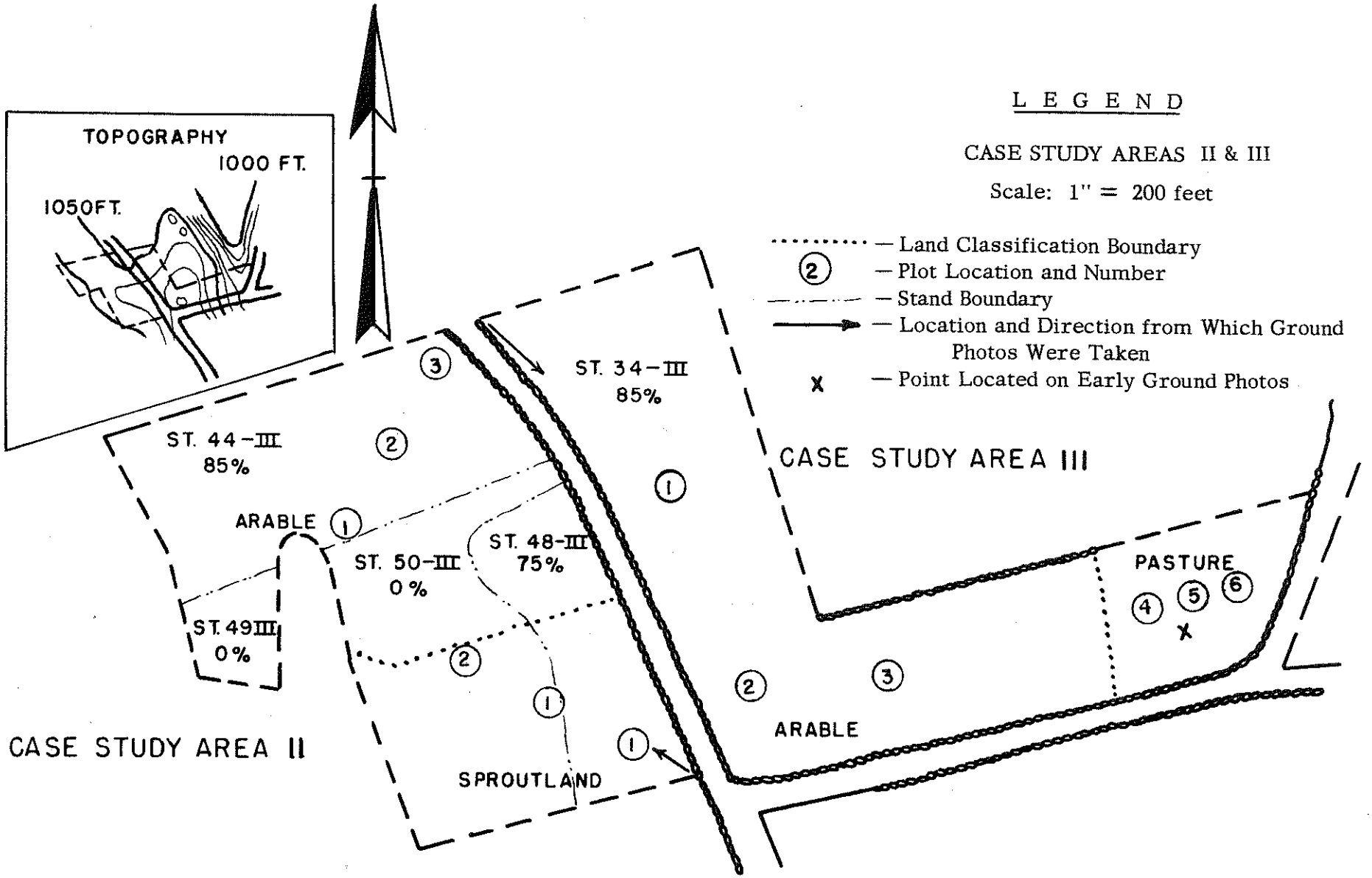
Stand Table No. I
Average number of planted and volunteer trees per acre by crown class.

	Dominant and Co-dominant		Intermediate and Suppressed		Total Number of Stems	
	Plan.	Vol.	Plan.	Vol.	Plan.	Vol.
Arable	375	0	44	0	419	0
Pasture	125	275	25	88	150	363
Sproutland	83	363	125	137	208	500

If average number of dominant and co-dominant trees is used as a gauge of establishment, it can be seen that arable land produced the largest number of established planted trees, pasture the next, and sproutland the least. Judging from the average number of dominants and co-dominants per acre of the volunteer species, competition was greatest in sproutland and least in arable land.

CASE STUDY AREA II

CASE STUDY MAP II



CASE STUDY AREA II

Stands 44, 46 and 50, Compartment III.

Land-Use Classification:

The study area includes a total of 7.1 acres classified as arable - 4.7 acres and sproutland -2.4 acres. The area is included in field photographs taken in 1939 and 1941 (see MDC Photos 2462 and 2594).

Soils and Site:

Arable land - soil is a poorly-drained to very poorly-drained Whitman muck. This area has a west to northwest aspect and is located in the lower section of a medium slope (100' - 300') of 0 to 5 percent grade. The topographic elevation ranges from 1050 to 1060 feet above sea level.

Sprontland - soils are well-drained Charlton fine sandy loam and moderately well-drained Sutton fine sandy loam over a water washed gravel. This area has a west aspect and is located in the middle section of a medium slope of 0 to 5 percent. Topographic elevation ranges from 1060 to 1080 feet above sea level.

Planting:

The entire study area was planted in the spring of 1937 with a mixture of white and red pine 2 - 2 transplant stock which was grown from seedlings acquired from the Massachusetts State nurseries and transplanted in the Quabbin Reservoir Watershed nurseries. These trees were planted using a "bucket mixture" system in which the white and red pine were planted just as they were delivered to the planting crew. No alternate row or other

systematic method of mixing the two species was employed. A 5' x 5' spacing was used throughout.

Initial Survival:

Snow (1946) reported that initial survival was very good in the areas planted in 1937. He estimated survival at 80 to 90 percent. No supplemental plantings were required in this study area.

Animal Damage:

No serious animal damage was reported in this area.

General Condition of the Plantations During the First Five Growing Seasons.

Arable Land:

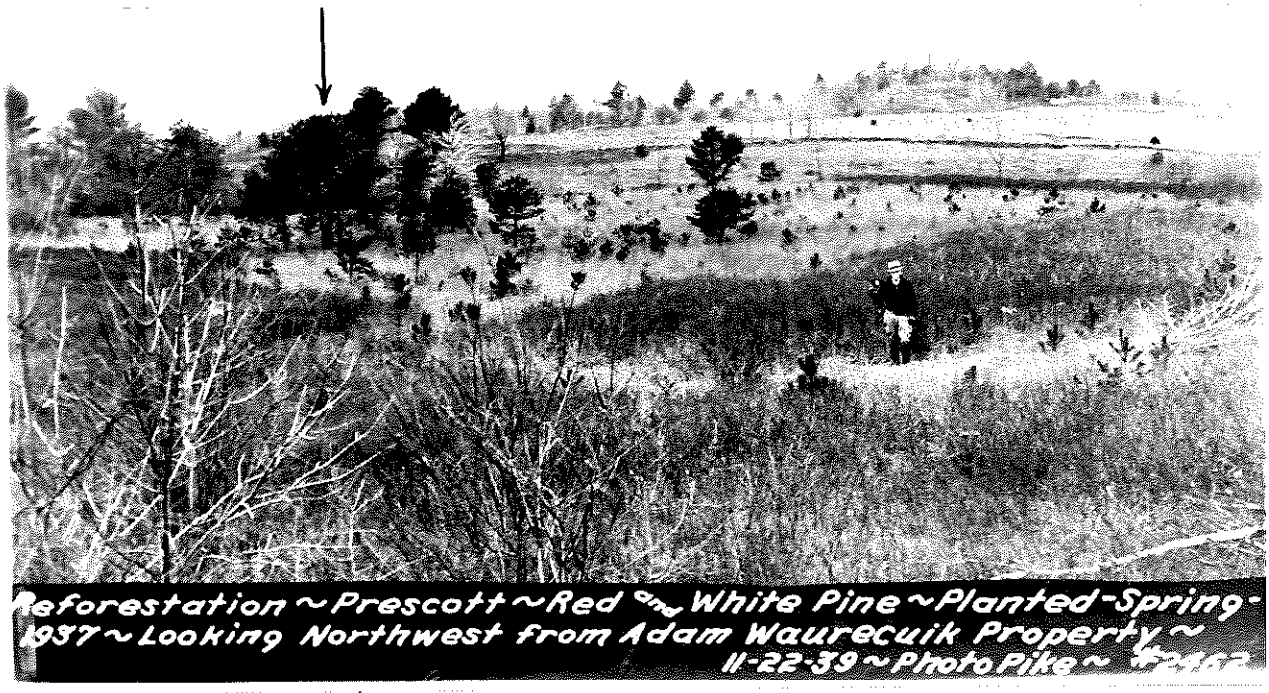
Examination of MDC Photos 2462 and 2594 show survival and development of the planted trees was relatively good. The young trees are well distributed over the area. MDC Photo 2594 shows that there are very few volunteer species growing above the planted trees. Most of the volunteers were located along the stone walls. Competition from grass and other herbacious perennials did not appear to have an adverse affect on the planted trees.

Increment borings, taken at four feet, from volunteers growing on the arable land at the time of the investigation indicate that these trees seeded into the area between 1935 and 1938. Most of the volunteers measured came into the area after it was planted (See Tables IX, X and XVI, Appendix B). There were probably not more than 125 volunteer species per acre at the time of planting and their average height would have been one to two feet (Figure II, Appendix B).

Sproutland:

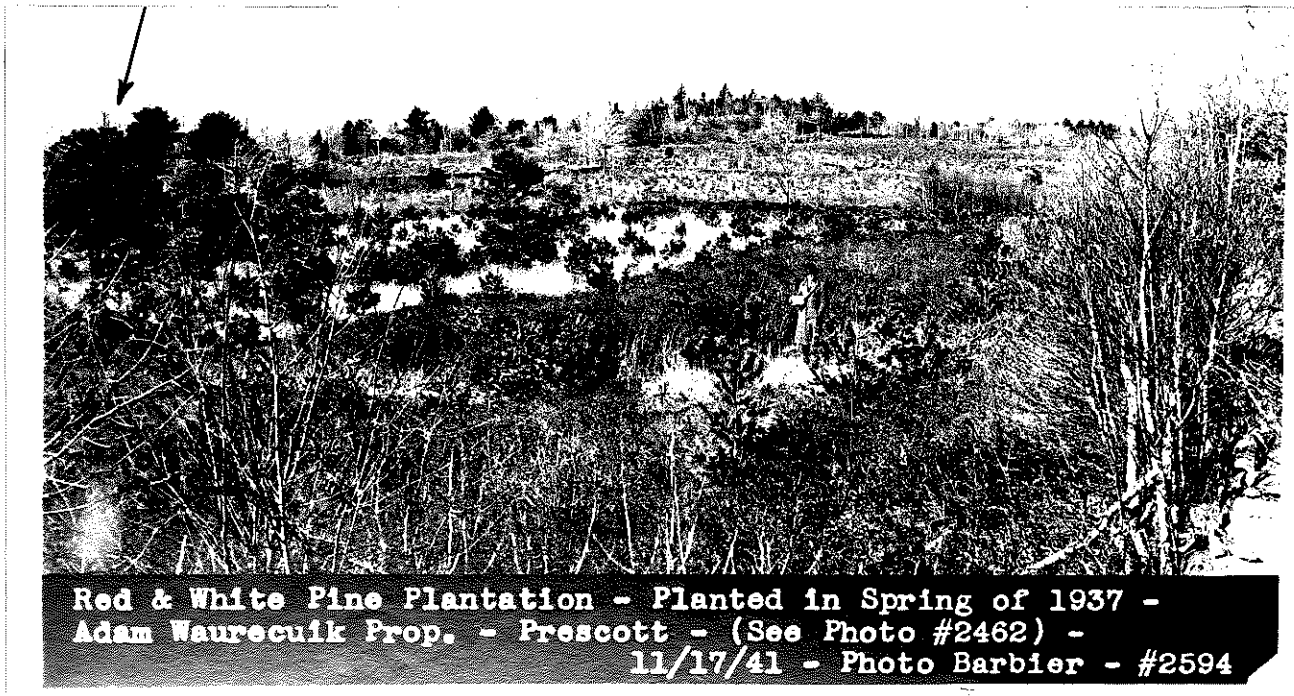
MDC Photos 2462 and 2594 show that the sproutland varied in compo-

Case Study Area II Three Growing Seasons After Planting.



MDC Photo 2462. Sproutland - Foreground, Arable Land - Center Background and Right Background.

Case Study Area II Six Growing Seasons After Planting.



MDC photo 2594. Same view as MDC photo 2462.

Case Study Area II Twenty-three Growing Seasons After Planting.

Photo No. 9. General view of Stand 48-III. This photo was taken directly across the road from where MDC photos 2462 and 2594 were taken and looking in the same direction. Photo by Dodge, 8/12/60.

Interior View of Stands 48 - III and 50 - III.

Photo No. 10. Interior view of Stands 48 - III and 50 - III. Double pitch pine in center of photo is the same as the one designated by the arrow in MDC photos 2462 and 2594. Photo by Dodge, 8/12/60.

sition from grass to a dense shrubby growth of two to four feet in height or, a combination of deciduous and coniferous tree species. Dissection of the volunteers in one of the more densely populated plots shows that there were a minimum of 400 volunteer species per acre growing in some sections of the sproutland at the time of planting (Tables XV and XVI, Appendix B). The range in average height of the volunteers was from three to five feet (Figure II, Appendix B). It is very probable that, in the denser areas of the sproutland, conditions at the time of planting were comparable to those in the sproutland of Case Study Area I.

During the first five growing seasons the planted trees became well established in the grassy areas and some began to outgrow the shrubby growth (NDC photos 2462 and 2594).

General Condition of the Plantations at the Twenty-third Growing Season.

Detailed descriptions of each plot in the two land classifications are found in Appendix B under Field Notes.

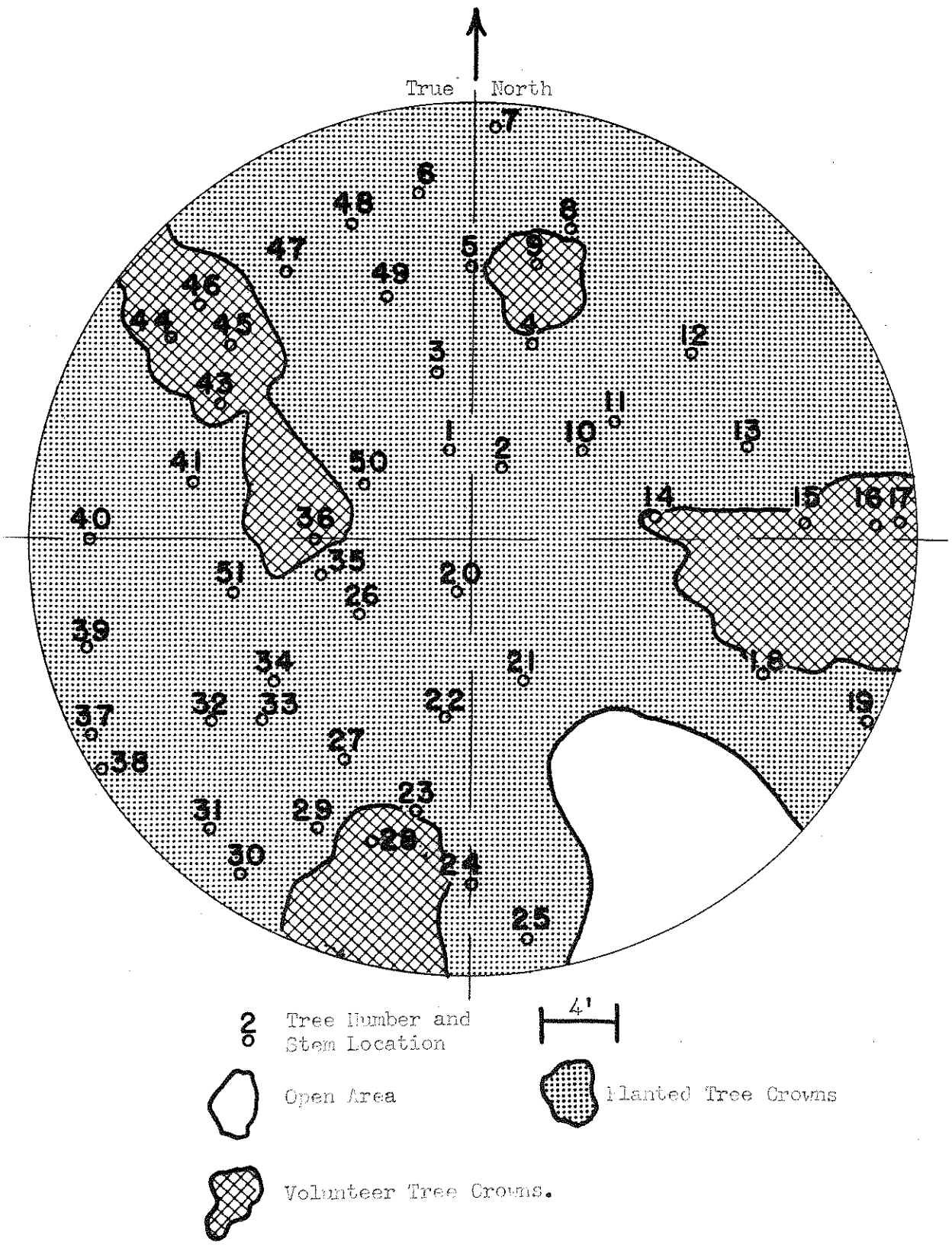
The general condition on the two land classifications is as follows:

Arable Land:

The arable land in this study area is located in the south end of Stand 44 - III. The area supports an average of 833 planted trees per acre, of which 325 are in the dominant and co-dominant crown class. White pine stems make up 68 percent of the planted trees in the dominant and co-dominant crown class. The range in number of planted trees per acre is from 550 to 1025. The area also supports an average of 262 volunteer tree species per acre of which 265 are in the dominant and co-dominant crown class. The range in number of volunteer tree species per acre is from 250 to 350. The average height of the planted trees is 28 feet and the average DBH is

FIGURE NO. XII

Map of Sten and Crown Distribution on
Plot No. 3, Stand 44 - III.



4.3 inches. The volunteer tree species average 27 feet in height and 3.5 inches in DBH. Figure No. XII shows the stem distribution and crown coverage of the trees on Plot No. 3, Stand 44 - III, and Photo No. 11 is a view of this plot looking to the northwest. The two red pines in the foreground of Photo No. 11 are tree Nos. 22 and 26 (Figure No. XII), with No. 22 being closest to the camera. The two largest white pines in the left center of Photo No. 11 are tree Nos. 34 and 51 (Figure No. XII).

Arable Land.
Red and White Pine - Twenty-three Years After Planting.

Photo No. 11. View of Plot No. 3, Stand 44 - III looking northwest across the plot. This area is judged to be typical of the general condition of this stand. Photo by Dodge, 8/12/60.

Plot No. 3, Stand 44 - III is judged to be typical of the entire stand. Woody vegetation is practically non-existent in the understory and, even in the small openings with no tree cover, the vegetation is primarily of herbacious perennials. The individual volunteer tree crowns were observed to take up much less of the area in the canopy than those observed in the sproutland areas in Case Study Area I and the present case

study area. This is judged to be another indication that the volunteers were as small or smaller than the planted trees at the time of planting, and under these conditions the volunteers would have to grow up through or along with the planted trees. The planted tree crowns would tend to keep the volunteer crowns smaller and could more successfully compete with the volunteer species.

Sproutland:

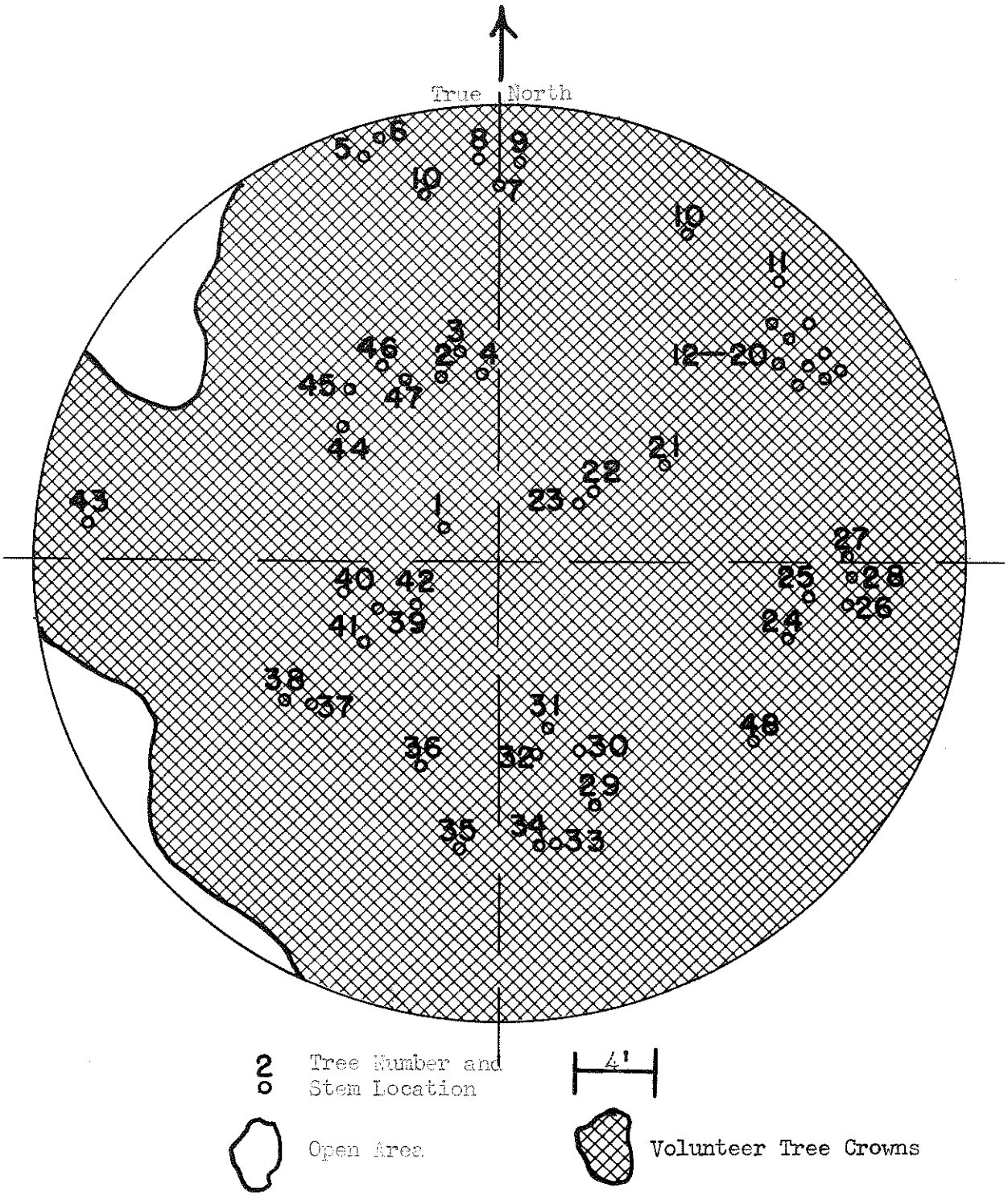
The sproutland is located in Stands 48 - III and 50 - III. This area supports two distinct types of vegetation which is represented by 75 percent establishment of planted trees in Stand 48 - III and 0 percent in Stand 50 - III.

This appears to be the same type of situation described under Sproutland in Case Study Area I; with one section of the sproutland supporting a dense growth of grasses, low-bush blueberry, bayberry and sweet-fern; and the other section supporting various volunteer tree species. Red maple, gray birch and pitch pine predominate in the latter section. No sample plots are located in the shrubby sections; however, these were noted during the field study (See Field Notes, Appendix B).

The sproutland supports an average of 283 planted trees per acre, of which 240 are in the dominant and co-dominant crown class. The range in number of planted trees per acre is from 0 to 475. Eighty-nine percent of the dominants and co-dominants are red pine. The area also supports an average of 450 volunteer trees per acre, of which 275 are in the dominant and co-dominant crown class. The range in number of volunteer trees per acre is from 75 to 1,200. All of the planted trees which became est-

FIGURE NO. XIII

Map of Stem and Crown Distribution on
Plot No. 2, Stand 50 - III.



ablished are found on well-drained Charlton fine sandy loam (See Field Notes, Appendix B). The shrubby vegetation is also found on the Charlton fine sandy loam and the volunteer trees are growing on both soil types.

Trees planted in the sproutland evidently became established only where there was very little or no woody vegetation to compete with them. It is possible that some of the planted pines grew up through the shrubby vegetation and suppressed it (MDC Photo 2594), although there is now no evidence of this.

The average height of the planted trees is 30 feet and the average DBH is 6.7 inches. Volunteers have an average height of 32 feet and an average DBH of 3.7 inches. Photo No. 10, page 67 shows the general condition of planted trees when they are growing in association with volunteer tree species and Figure No. XIII shows the stem and crown distribution of volunteer trees where no planted trees became established. Photo No. 12 shows the type of vegetation existing on Plot No. 2, Stand 50 - III. Photo No. 13 shows the same stand after the volunteer stems were dissected.

Some white pine existed in the understory of the areas dominated by volunteers but these could not definitely be identified as planted trees because there were white pine seed trees located off the original planted area which may have produced seed that germinated and grew in the planted area. Several dead red pines were found in the sproutland area (See Field Notes, Appendix B). This indicates that the sproutland was planted because there are no native red pines to produce seed in this general area.

Summary of Observations on Case Study Area II.

In this case study, a comparison of the performance of the planted

Sproutland Twenty-Four Years After Planting.

Photo No. 12. Looking northwest across Plot No. 2, Stand 50 - III. Axe is in tree No. 1 (See Figure XIII for location). Note that some vegetation exists in the understory, consisting of high and low-bush blueberry, bracken fern and grass. Photo by Dodge, 6/21/60.

Same Area After Dissection.

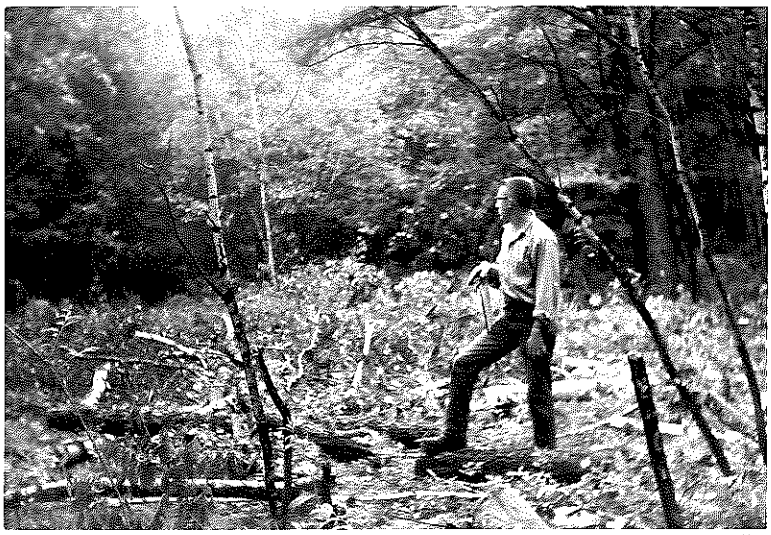


Photo No. 13. View of Plot No. 2, Stand 50 - III after the volunteer stems were dissected. Photo by Dodge, 6/24/60.

FIGURE NO. XIV - A

Comparative Height Growth of White Pine and Volunteers on Arable Land.

Relationship of average total height to age of planted white pine and deciduous volunteer species on the Prescott Peninsula, Quabbin Reservoir Watershed. Taken from plot measurements (See Figures II and IV, Appendix B).

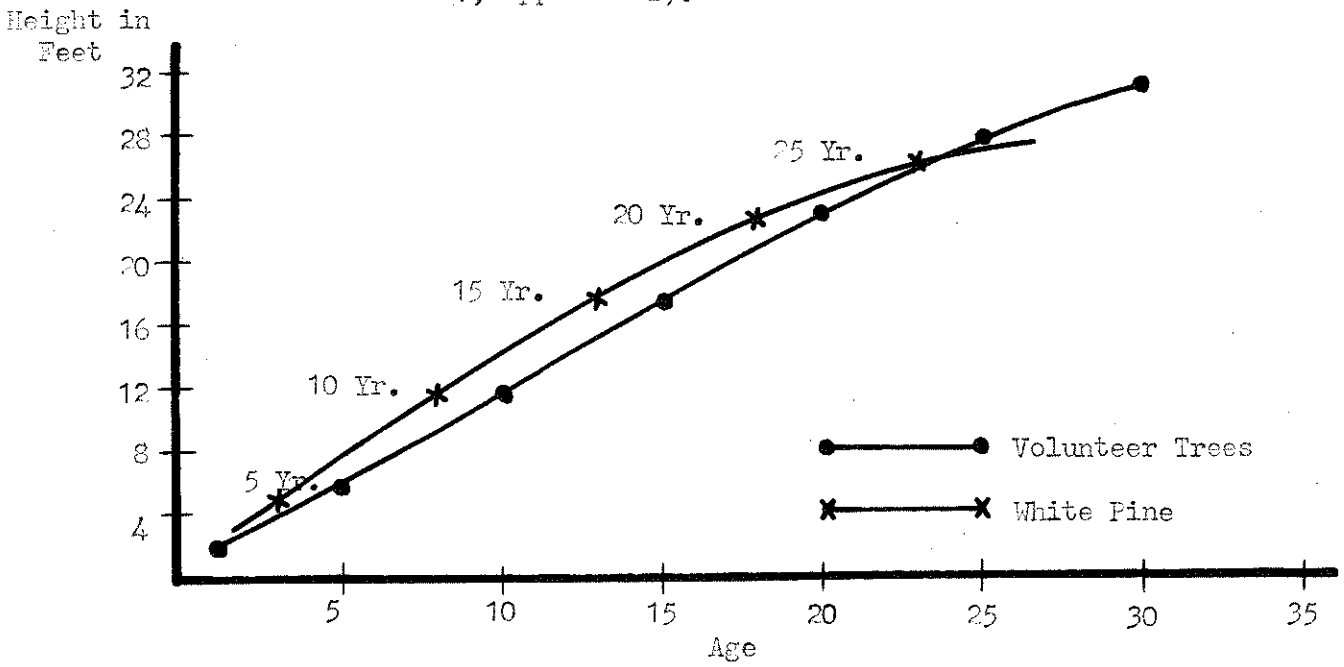
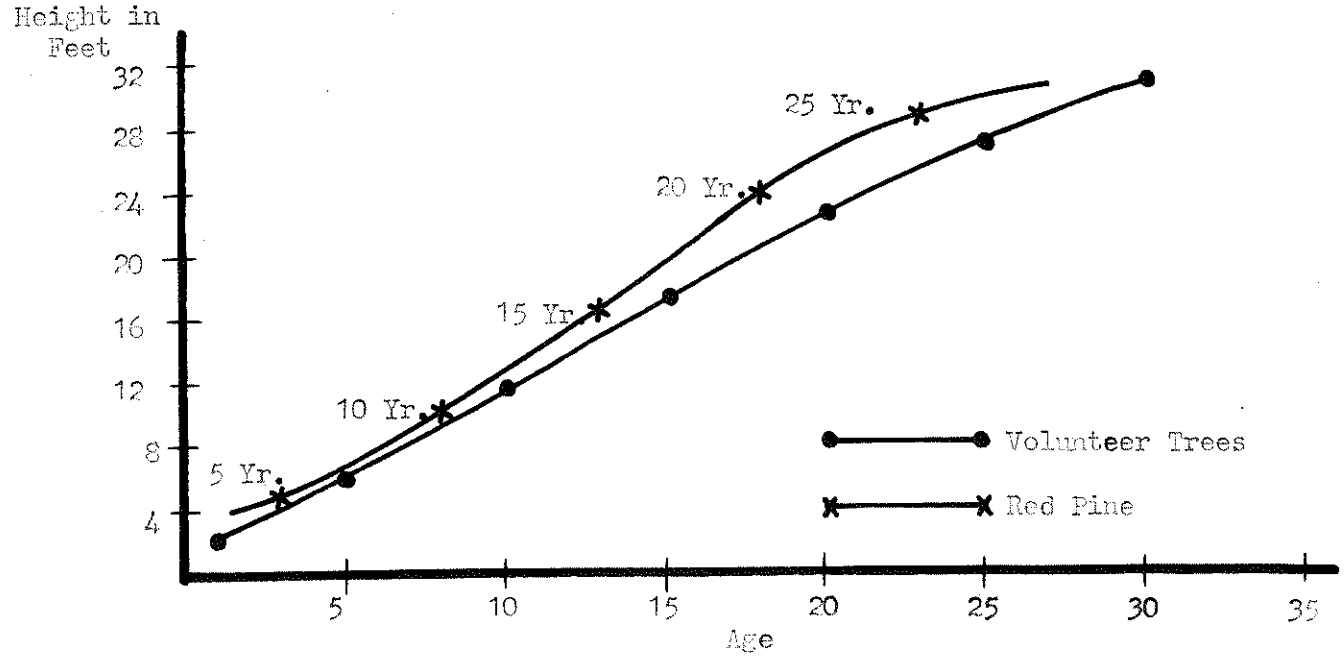


FIGURE NO. XIV-B

Comparative Height Growth of Red Pine and Volunteers on Arable Land.



Relationship of average total height to age of planted red pine and deciduous volunteer species on the Prescott Penninsula, Quabbin Reservoir Watershed. Taken from plot measurements (See Figures II and V, Appendix B).

trees and volunteer trees can be made only on the arable land. Figures No. XIV, A and B show that if four year old white and red pine transplant stock is planted in association with one year old volunteer tree species, the pines will average more height growth each year for the first 25 years. The planted trees had a relatively good chance of becoming established on the arable land in this case study area because there were probably not more than 125 volunteer trees per acre at the time of planting.

This type of comparison cannot be made on the sproutland in this case study because there were no identifiable planted trees existing where a dense cover of volunteer tree species was found. It appears that, in the sproutland, planted trees became established only where competition from volunteer trees was lacking and where competition from shrubby vegetation was at a minimum.

Stand Table No. 2 shows the average number of planted and volunteer trees per acre in each land-use area and the average number of trees in the dominant and co-dominant crown class.

Stand Table No. 2.
Average number of planted and volunteer trees per acre by crown class.

	Dominant and Co-dominant		Intermediate and Suppressed		Total Number of Stems	
	Plan.	Vol.	Plan.	Vol.	Plan.	Vol.
Arable	325	265	508	17	833	282
Sproutland	240	275	43	175	283	450

If average number of dominant and co-dominant trees is used as a gauge of establishment, it can be seen that arable land produced a much larger number of established planted trees than did the sproutland. Stand Table No. 2

suggests that this sproutland did not affect establishment of the planted trees as severely as the sproutland in Case Study No. 1. The author believes that there were probably more small openings in the sproutland of this case study area where planted trees could become established, and these small openings were primarily in the shrubby areas (See MDC Photos No. 2462 and 2594, also Case Study Map II).

CASE STUDY AREA III

CASE STUDY AREA III

Stand 34, Compartment III.

Land-Use Classification:

The study area includes a total of 4.6 acres classified as; arable - 3.4 acres, and pasture - 1.2 acres. The location of this study area is shown on Case Study Map II included in the previous case study. This study area was used because it is included in a field photograph showing the condition of the planted area five years after planting (NDC Photo 2596), and, although this area was classified under two types of land-use, the over-all percentage of establishment was the same (See Case Study Map II).

Soils and Site:

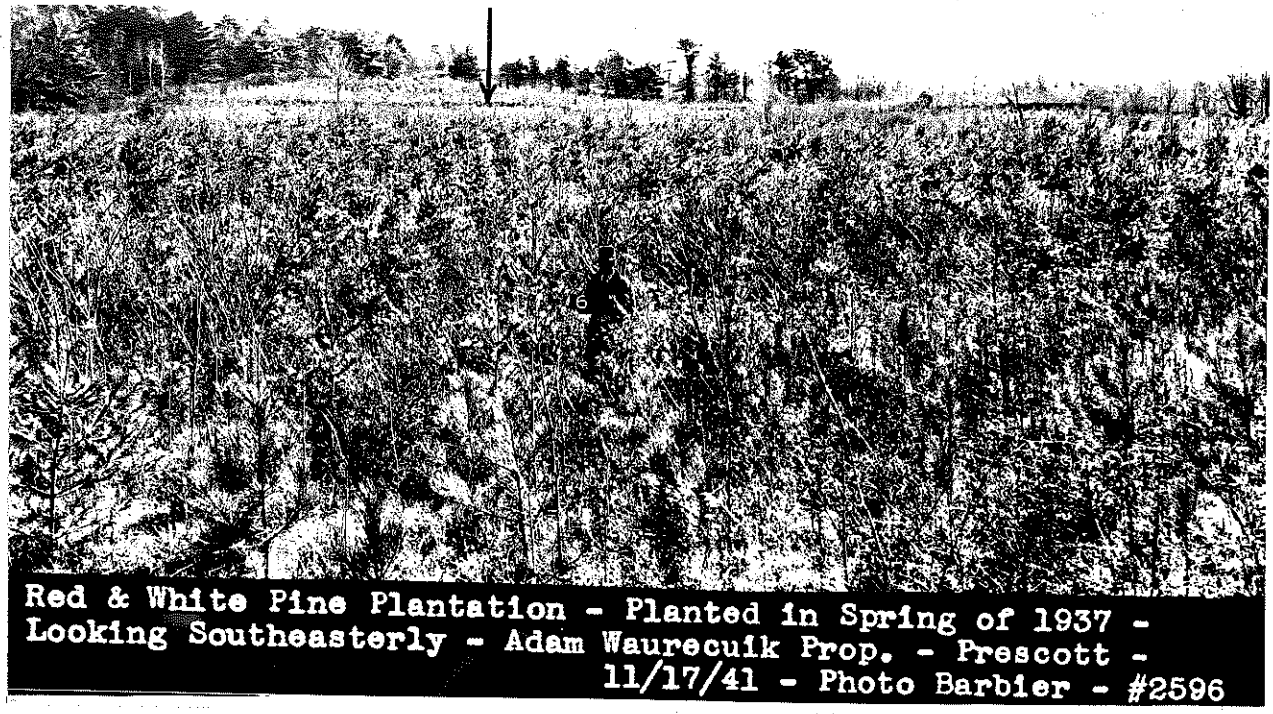
Arable land - soil is a well-drained Charlton fine sandy loam. This area has an east to northeast aspect and is located on the upper and middle sections of a medium slope (100' - 300') of 0 to 15 percent grade. Topographic elevation is from 1040 to 1080 feet above sea level.

Pasture - soil is a well-drained Charlton fine sandy loam. This area has an easterly aspect and is located on the middle and lower sections of a medium slope of 0 to 10 percent. Topographic elevation is from 1020 to 1040 feet above sea level.

Planting:

This area was planted with the same type of white and red pine planting stock and during the same planting season as the area included in Case Study Area II.

Case Study Area III After the Fifth Growing Season.



MDC Photo 2596. General view of Case Study Area III after the fifth growing season. Note that most planted trees appear to be as tall or taller than the volunteer deciduous trees. Arrow points to pasture.

Case Study Area III at the Twenty-third Growing Season.

Photo No. 14. Photo taken across the road from where MDC Photo 2596 was taken (See Case Study Map II). Photo by Dodge, 8/12/60.

Initial Survival:

Initial survival conditions were similar to those on Case Study Area II.

Animal Damage:

No serious animal damage was reported in this area.

General Condition of the Plantation at the End of the Fifth Growing Season.

Arable Land and Pasture:

MDC Photo 2596 shows that the arable land and pasture were very similar in appearance at the end of the fifth growing season. There was a relatively dense growth of volunteer tree species growing with the planted trees. In most cases, however, the planted trees were equal in height or taller than the volunteers.

Ring counts, at four feet, of volunteers found in the area indicate that volunteers seeded in between 1929 and 1938. There was a minimum of approximately 15 volunteers per acre growing in the area at the time of planting in 1937 (See Tables XVIII, XXI, XXII, XXIII, and XVI, Appendix B).

General Condition of the Plantations at the Twenty-third Growing Season.

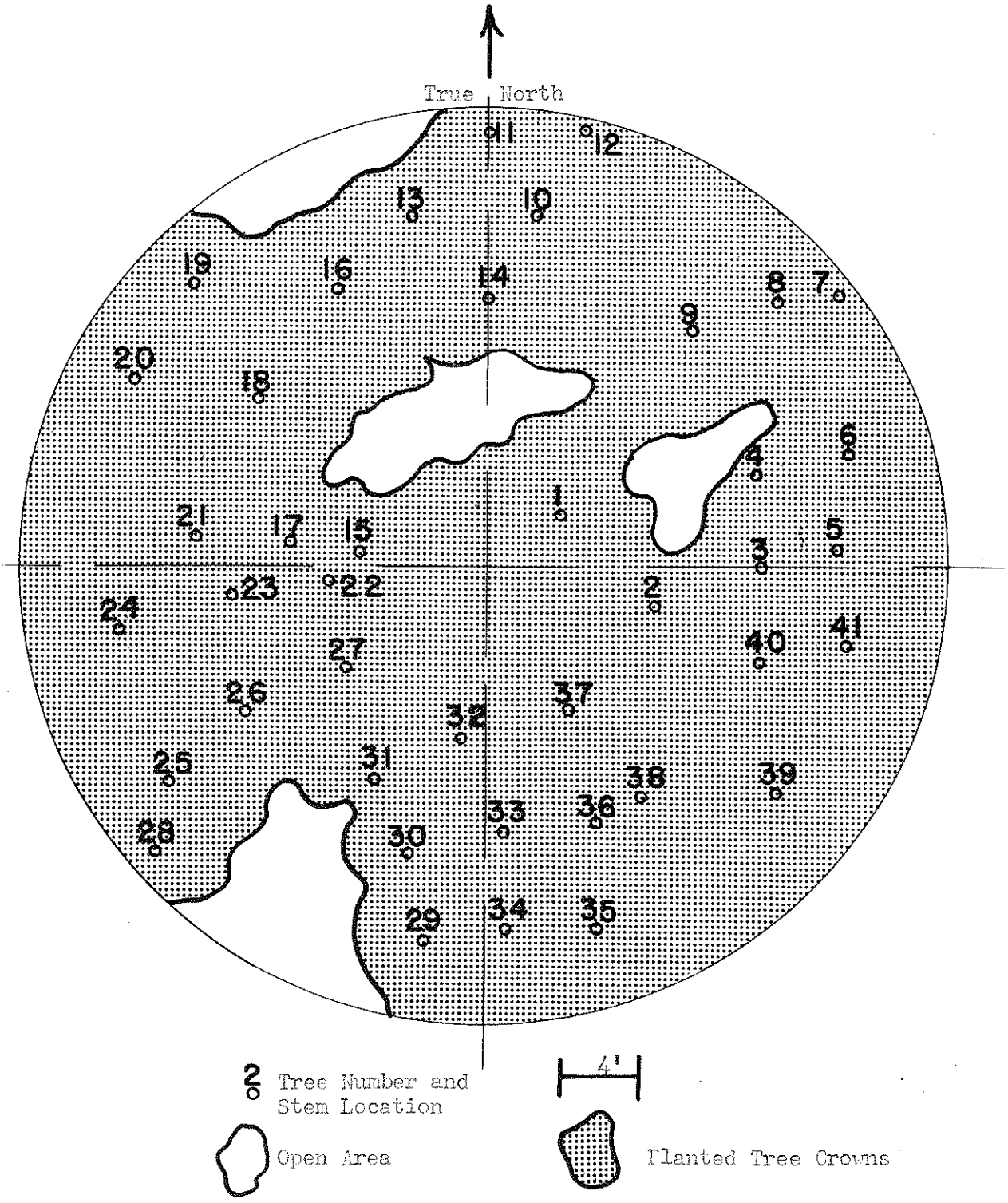
Detailed descriptions of each plot in the two land classifications are found in Appendix B under Field Notes. The general condition on the two land classifications is as follows:

Arable Land:

The arable land comprises about three-quarters of this study area (See Case Study Map II). This area supports an average of 1082 planted trees per acre, of which 75% are in the dominant and co-dominant crown

FIGURE NO. XV

Map of Stem and Crown Distribution on
Plot No. 3, Stand 34 - III



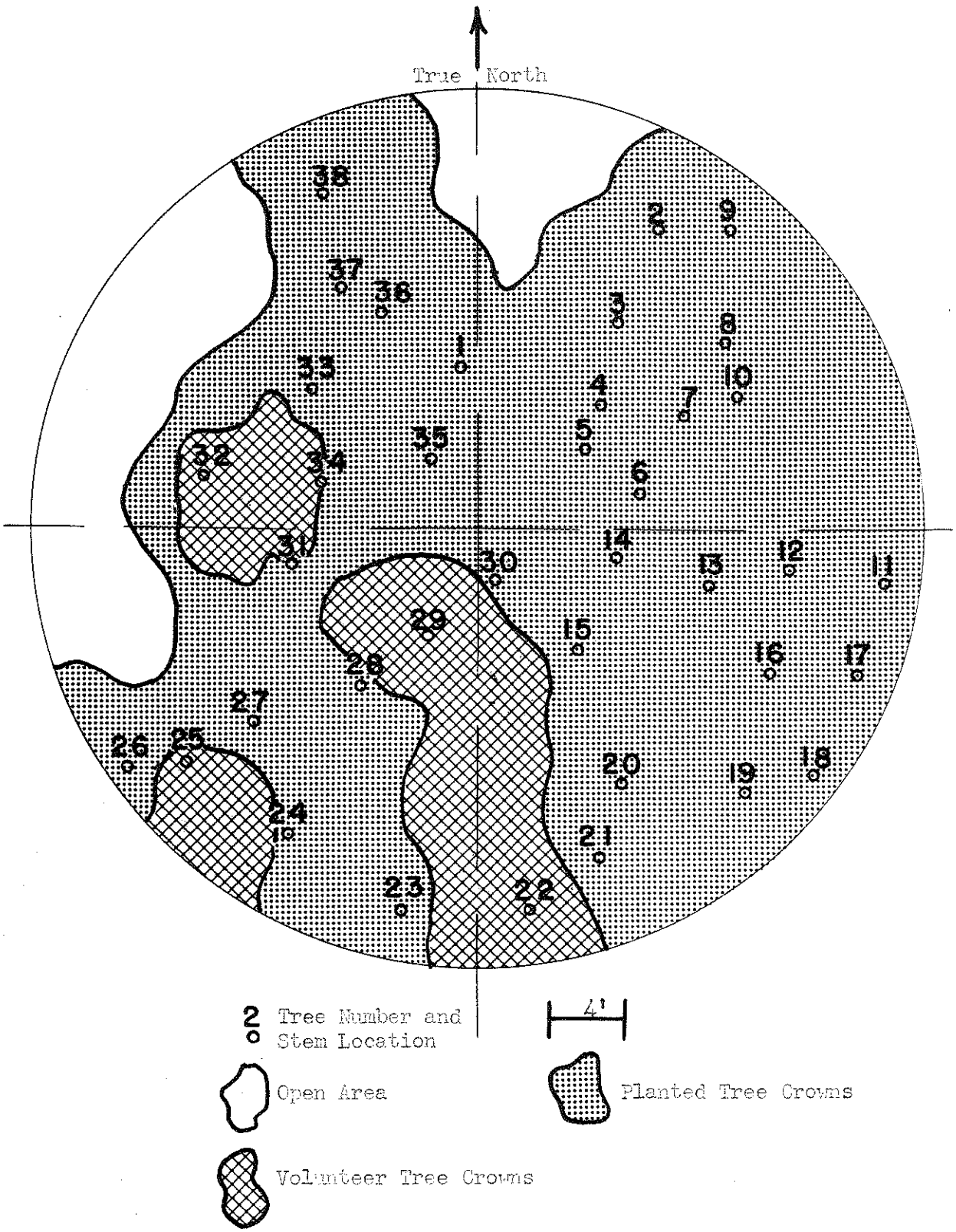
class. The number of planted trees per acre ranges from 1025 to 1200. This area also supports an average of 40 volunteer deciduous trees per acre, and all are in the co-dominant crown class. The range in number of volunteer trees per acre is from 0 to 125. The average height of the planted trees is 26 feet and the average DBH is 5.4 inches. The volunteer species average approximately 27 feet in height and 2.8 inches in DBH. Figure No. XV shows the stem and crown distribution on Plot No. 3, Stand No. 34 - III, and Photo No. 15 shows what is judged to be the typical appearance of the plantation on arable land.

Typical Arable Land in Stand No. 34 - III

Photo No. 15. Looking north through Stand No. 34 - III. Photo by Dodge, 8/12/60.

FIGURE NO. LVI

Map of Stem and Crown Distribution on
Plot No. 6, Stand 34 - III.



Pasture:

The pasture is located in the eastern section of Stand No. 34 - III (See Case Study Map II). This area supports an average of 1108 planted trees per acre, of which 783 are in the dominant and co-dominant crown class. The range in number of planted trees per acre is from 850 to 1325. This area also supports an average of 65 volunteer deciduous trees per acre and 58 of these are in the dominant and co-dominant crown class. The number of volunteer species per acre is from 25 to 100. The planted trees average 28 feet in height and 4.9 inches in DBH. The volunteer trees have an average height of 25 feet and an average DBH of 3.4 inches. Figure XVI shows the stem location and crown distribution on Plot No. 6, Stand No. 34 - III. Photo No. 16 is a view of the pasture looking north from the road along the south boundry of the area (See Case Study Map II).

Pasture Twenty-three Years After Planting.

Photo No. 16. Looking north to the pasture section of Stand No. 34 - III. Photo by Dodge, 8/12/60.

Summary of Observations on Case Study Area III.

There is very little difference in comparisons made between the growth performance of planted trees on arable land and on pasture in this case study because the planted trees became established equally well on both areas. The height growth of the planted trees was similar to that of the planted trees in the arable land in Case Study Area II (See Figures XIV - A and B), and was sufficient to outgrow or equal the height growth of the volunteer trees.

MDC Photo No. 2596 suggests that there were many more volunteer stems per acre five years after planting than were found at the time of this investigation. It is possible that the planted trees did suppress many of the volunteers in the area.

The average height of the planted trees on the arable land is two feet less than those planted on the pasture. This is probably not significant because all of the trees measured on arable land were white pines which had been weeviled several times and consequently, were shorter than the average height of all trees in the stand.

Stand Table No. III summarizes the condition of the planted trees on the two different types of land-use in terms of stems per acre:

Stand Table No. III
Average number of planted and volunteer trees per acre by crown class.

	Dominant and Co-dominant		Intermediate and Suppressed		Total Number of Stems	
	Plan.	Vol.	Plan.	Vol.	Plan.	Vol.
Arable	758	40	324	0	1082	40
Pasture	783	58	325	7	1108	65

If the average number of dominant and co-dominant trees is used as a gauge of the relative amount of competition in each type of land-use, it can be seen that competition was only slightly greater in the pasture. However, if the same criterion is used as a gauge of establishment, it is evident that planted trees became better established in pasture. The difference between the number of dominant and co-dominant stems per acre on arable land and pasture is so small in this case study that it seems competition was not a significant factor limiting establishment in either area. Probably both areas became well established because there was a minimum of competition at the time of planting and volunteers which seeded in after planting could not compete with the planted trees.

DISCUSSION

Data:

For the purposes of this investigation, the definition of establishment, as stated by the Society of American Foresters (1950) depends so heavily on subjective judgments that it could not be uniformly applied. Therefore, a more objective criterion was selected.

Webster's New International Dictionary of the English Language (1935) defines established as: "to originate and secure the existence of". Under this definition an established forest plantation would be one in which the planted trees dominated the main canopy over the entire planted area. In this investigation, where the trees had been planted for 17 years or more, so that the crowns were large enough to close, the definition of a fully established plantation becomes;

> A plantation in which the crowns of the planted trees completely dominate the original planted area so as to exclude other tree species.

A working hypothesis was set up that plantations can be established in varying degrees and can be distinguished by percentage of crown closure. It was further hypothesized that conditions, in the study area, such as previous land-use, competition, excess moisture, deer damage and porcupine damage would limit the degree of establishment and would be generally effective in all crown closure classes.

It might be assumed that, if the factors affecting planted tree growth were generally effective on all sites, the planted acreage would be evenly distributed among the crown closure classes. However, this is not the case

because Table I shows that, on the 3,223.9 acres of planted area, there is some acreage in each crown closure class from 0 to 95 percent, but it is also obvious that only 6.7 percent of this area falls within the 5 to 55 percent crown closure classes. There is a strong tendency for the plantations to either have no trees in the canopy, or a crown closure of 55 percent and more. This fact becomes even more apparent in the data in Table II which indicate that, in the area classified as to previous land-use, an average of only 5.4 percent of the total acreage is within the 5 to 55 percent range of crown closure. Table II also shows that these percentages of establishment are found on only 2.7 percent of the sproutland.

Figure No. V illustrates that there is a vast difference between arable and sproutland in the 0 and 55 to 95 percent crown closure classes. This figure also shows that establishment in pasture parallels that of the arable land but there is more zero crown closure and somewhat less area in the 55 to 95 percent classes.

This uneven distribution of the acreage among the establishment classes, on all types of land-use, shows that factors limiting crown closure are either not generally distributed, or they are not everywhere present to a limiting degree.

Tables III, IV and V show that of the limiting factors studied competition was most widely distributed, being judged of primary importance on 57 percent of the arable land, 75 percent of the pasture, and 81 percent of the sproutland. These tables also show that excess moisture has more impact on the lower crown classes on arable land than on the other types of land-use. Generally, the adverse factors, other than competition, appeared

to be most prevalent in the higher crown closure classes.

Figures derived from the tables show that, on the entire study area, there are no planted trees in the canopy on approximately one-half (55 percent) of the acreage. Competition accounted for over two-thirds (68 percent) of these blanks.

The case studies reveal several patterns of fact which indicate that plantation establishment is related in a large degree to the intensity of competition found on arable land, pasture and sproutland at the time of planting.

If the three case studies are considered together, it is apparent that competition from volunteer tree species, at the time of planting, was greatest on sproutland, while arable land and pasture supported approximately the same average number of volunteer tree species per acre at the time of planting.

If a comparison is made between the same types of land-use in Case Studies I, II and III it is obvious that none of these types, in one case study area, produced a similar number of dominant and co-dominant trees, either volunteer or planted, as its counterpart in another case study area. In fact, a comparison of the two areas of pasture suggests that there can be an extreme range in the number of dominant and co-dominant trees found in any one kind of previous land-use class. The two patterns of fact which remain consistent are; (1) The more dominant and co-dominant volunteer tree species found per acre, the fewer dominant and co-dominant planted trees exist; and (2) There is always a greater average number of volunteer trees dominating the area on sproutland than on pasture or arable land.

The fact that there is a variation in intensity of competition within

the same land-use is shown in the three case studies. There also seems to be a coincidence between soil texture and drainage, and the variation in the intensity of competition. The sproutland is located on fine sandy well-drained, stony moderately well-drained, and very stony poorly-drained soils, and the intensity of competition, in terms of crown closure, increase with stoniness and wetness of the soil. The same pattern of fact holds true for pasture. Arable land is found on stony, well-drained and poorly to very poorly drained soils; and the competition increases with wetness. These patterns of fact suggest the possibility that volunteer species are better able to compete with planted trees on the wetter soils.

Raup and Carlson (1941) state that, in the town of Petersham, Massachusetts, the principal industry was agriculture. Between 1865 and 1905 the competition of western cereals brought a change in agriculture from the production of cereals to an emphasis on raising dairy products, poultry, fruits and vegetables, or the farms began to be abandoned as the owners went to work in nearby industrial areas. Whole farms were not abandoned at one time but the less valuable land was dropped from cultivation first.

Prescott was a hill town similar to Petersham in geographic location and the principal industry was agriculture (Howe, 1951). It is this author's judgment that agriculture followed the same pattern as that in Petersham, and farm abandonment was a gradual process with the least valuable land being abandoned first on each farm. Stoniness of the soil may have been more influencial in land abandonment than poor drainage. The decreasing need for intensively cultivated land would have allowed the farmer to abandon the difficult areas of cultivation first. Horses and oxen were still the primary

means of cultivation during the last years of agriculture in Prescott and, with the use of these animals, stony land was harder to cultivate than moist land. The poorly to very poorly drained arable land in Case Study Area II was evidently much better suited for cultivation than the moderately well-drained sproutland because it was not stony.

The fact that the wetter arable land in Case Study Area II supports more volunteer trees than the well-drained arable land in the other case study areas does not obscure the fact that the planted trees grew sufficiently well to occupy 85 percent of the canopy on the wetter land. Also, the plot data on sproutland indicates that wetter sites support more volunteer trees per acre than drier sites. There is, however, a low percentage of plantation establishment in the sections of sproutland which supported a relatively high number of volunteers per acre, or a dense growth of shrubby vegetation at the time of planting regardless of the degree of wetness.

The patterns of fact developed in this investigation indicate, to the author, that on planting sites similar to those encountered in the study area, the primary factor limiting plantation establishment is the intensity of land-use on the site at the time of planting, or just prior to planting. The data suggests that the lower intensities of land-use allow more volunteer tree species to invade the area prior to planting and there will be more competition in these areas than on the arable land. This investigation shows that, within each land-use area, competition limits the percentage of crown closure more than any other factor examined, but competition is always greater in sproutland than in arable land. It appears that conditions on pasture can resemble those on sproutland at the time of planting but

usually parallel those conditions found on arable land, with the exception that pasture will probably contain somewhat more competition. The case study areas indicate that competition may increase as the soil becomes wetter and more stony. It is felt that there is not enough data to completely substantiate this though the general trend should be considered as a possibility.

To further show the pattern of establishment on the study area, Acceptable Plantation Over-lays (Figures A through H, Appendix A) were constructed for each Land-Use Base Map. These over-lays contain all planted areas with 55 percent or more crown closure. Acceptable plantations must be subjectively determined by each forest land manager, depending upon what percentages of establishment are acceptable to him. Because of the subjectivity involved, the system of combining Land-Use Base Maps with Acceptable Plantation Over-lays is discussed here only as a technique. Fifty-five percent crown closure was selected as the lower limit of acceptibility because areas with 55 percent establishment contained 375 to 500 evenly distributed, dominant and co-dominant planted trees per acre (Field Notes, Appendix B). It was felt this condition was similar to that described in the definition of acceptable plantations by Zillgit and Rotty (1955).

If 55 percent crown closure is considered to constitute an acceptable plantation, the Acceptable Plantation Overlays, combined with Land-Use Base Maps (Figures I - VIII, Appendix B) will show that most of the acceptable plantation acreage is located on land which was classified as arable or pasture at the time of planting. If the data presented are considered while observing acceptable plantations and land-use maps, the observer can

conclude that 57.6 percent of the entire planted area supports acceptable plantations, 59.5 percent of the planted pasture supports acceptable plantations, but acceptable plantations are found on only 25.3 percent of the planted sproutland.

If this study area, which received no silvicultural treatment subsequent to planting, is compared with the planted areas on the Harvard Forest, the following information is significant:

1. Zero percent crown closure is found on 35.7 percent of the total planted area included in this investigation.
   a. Competition is the primary influence on 63 percent of this area.
   b. Excess moisture is the primary influence on 14.3 percent of this area.
   c. Animal damage is the primary influence on 13.1 percent of this area.
   d. Factors other than those listed above are involved in 9.6 percent of this area.
2. Zero percent crown closure is found on 15.5 percent of the total area planted with conifers on the Harvard Forest[1].
   a. Competition and excess moisture were the primary influence on 32.6 percent of this area.
   b. Animal, disease and mechanical damage were the primary influence on 2.1 percent of the area.
   c. Fire was the primary influence on 41.2 percent of the area.

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[1]Summary of discontinued plantations on the Harvard Forest, 8/12/59. On file at the Harvard Forest, Petersham, Massachusetts.

d. Hurricane blow-down was the primary influence on 22.4 percent of the area.

e. Factors other than those listed above are involved in 1.7 percent of the area.

The planted areas on the Harvard Forest, in contrast to the study area, received intensive silvicultural management subsequent to planting. Spurr (1956) notes that there was an average of four cleanings. Stransky (1953) reports that 90.6 percent of the area planted on the Harvard Forest was classified as brushland, cutover cordwood land, cutover sawtimber land or underplanted woodland.

The comparison between the study area and the planted area on the Harvard Forest indicates that total loss of planted areas is much less when silvicultural treatments, after planting, are included in the management of planted areas. It is also suggested that this comparison further indicates the probability that wetter soils do not necessarily limit plantation establishment when competition is controlled or absent.

Discussion of this Investigation:

This investigation of patterns of fact on a large planted area for the purposes of analyzing plantation establishment was completed in a relatively short period of time.

This type of investigation should be considered as a preliminary type of research which can be used to point out the problems affecting plantation establishment and requiring more intensive research.

The present study does point the way for future intensive research into many problems of plantation establishment. For example, the fact that a plantation can be established on any one type of land-use or soil-moisture regime does not mean that it is practical to do so.

Probably the most pressing question to be answered is; what percent-

age of crown cover is required to make it economical to plant trees under similar conditions to those encountered in the study area? Perhaps 55 percent crown cover will produce the greatest financial return, especially if the other 45 percent of the canopy is dominated by deciduous tree species. The volume of wood may be as great, and the wood as potentially valuable, as that found in a planted area which is 95 percent established. The answers to this question cannot be found until an intensive investigation is made into the site factors involved in the production of volume on these areas.

The data show that in many areas where competition has limited the percentage of crown closure there are many planted trees existing in the understory. It is possible that there is a point in time, after planting, when it is most desirable to remove this competition in order to provide the desired percentage of plantation establishment. The study area contains planted trees in many stages of development, a situation which provides an excellent opportunity for further investigating the effect of competition on planted trees in different stages of development.

This investigation cannot predict the future performance of the trees in the various percentages of crown closure. Therefore, it is felt that documentation of the study area should be continued throughout the life of the plantations until the establishment processes are fully understood.

SUMMARY

A reforested area comprising approximately 3,200 acres of the Quabbin Reservoir Watershed was examined, through the use of aerial photo interpretation and case studies, to study the effects of various factors which limit plantation establishment in a planted area that receives no silvicultural treatment after planting until commercial thinnings can be undertaken.

Patterns of fact were developed during the investigation which lead to the following conclusions:

1. Plantations within the age group of 17 to 25 develop with the percentage of planted trees dominating the canopy ranging from 0 to 95 percent. There is, however, a strong tendency for these areas to have either no planted trees in the canopy or they dominate 55 percent and more of the canopy.

2. Land-use prior to planting influences plantation establishment to a great degree. Sproutland supports the least area of planted trees dominating 55 percent or more of the canopy and arable land supports the most. Pasture tends to parallel the establishment process on arable land but there is greater area with no crown closure and somewhat less area in the 55 to 95 percents of crown closure.

3. Competition is the primary limiting factor on each of the previous land-use classes. Excess moisture, animal damage and other factors do not seem to limit percent of establishment except in the higher percentages, and then primarily on arable land and pasture.

4. Comparison of this study area with the planted areas on the Harvard Forest, Petersham, Massachusetts shows that the total loss of planted trees is much less when silvicultural treatments after planting are included in the management of planted areas.

It is suggested that this is a preliminary type of research which points out the problems affecting plantation establishment which require intensive research. Several problems are suggested which will require a more intensive type of research on the area in the future.

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APPENDIX A

Land-Use Base Maps and Acceptable Plantation Overlays

APPENDIX A MAPS ARE LOCATED IN THE VERTICAL MAP FILE IN THE RECORD VAULT.

APPENDIX B

Field Notes, Tables and Figures Produced From and Utilized in Case Study Areas

FIELD NOTES
STAND #146 - II
PLOTS ON ARABLE LAND

N 17° W of True North - 15 chains - 4 plots @ $1\frac{1}{2}$, $5\frac{1}{2}$, $9\frac{1}{2}$; & $12\frac{1}{2}$ chains - begins at point "A" on Case Study Map.

PLOT #5.

1. 27 planted trees. 20 in dominant & co-dominant crown class.
2. No volunteer deciduous species. No volunteer conifers.
3. Only ground vegetation is a few (5 - 10) patches of polytricum moss & ferns.
4. Soil is a well-drained Charlton Fine Sandy Loam.
5. SW aspect - mid-slope on a long slope (300' +) of 5 - 10%.

PLOT #6.

1. 8 planted trees. 6 in dominant & co-dominant crown class.
2. No volunteer tree species.
3. Open areas (30' +) have all herbacious ground cover of grass, milkweed, blackberry vines, grape vines and golden rod.
4. Some dead woody bushes obviously killed from repeated deer browsing.
5. W aspect - mid-slope on a long slope (300' +) of 5 - 10%.
6. Soil is a well-drained Charlton Fine Sandy Loam.

PLOT #7.

1. 21 planted trees. 18 in dominant & co-dominant crown class.
2. No volunteer woody stems.
3. Soil is a well-drained Charlton Fine Sandy Loam.
4. W aspect - mid-slope on a long slope (300' +) of 5 - 10%.
5. Mapped the plot.
6. Larch is deformed by porcupine damage.

PLOT #8.

1. 11 planted trees. 9 in dominant & co-dominant crown class. Openings contain grass & a few (5-10) clumps of ferns.
2. Soil is a well-drained Charlton Fine Sandy Loam.
3. SW aspect - upper-slope on a long slope (300' +) of 5 - 10%.

FIELD NOTES
STAND #146 - II
PLOTS ON SPROUTLAND

S 38° 30' W of True North - 10 chains - 4 plots @ 2,4,6, & 8 chains - begins at point "A" on Case Study Map.

PLOT #1.

1. 29 volunteer deciduous trees, primarily red maple, on this plot.
2. 23 planted trees still exist.
3. Only 10 planted trees are in the dominant & co-dominant crown class.
4. 23 of the deciduous trees are in the dominant & co-dominant crown class.
5. All volunteers & planted trees are growing on mounds 6 - 12 inches above the general micro-relief - most pronounced are the mounds upon which the dominants and co-dominants are growing.
6. Soil is poorly drained Leicester Very Stony Loam.
7. SW aspect - lower slope of long slope (300' +) of 0 - 5%.

PLOT #2.

1. 34 deciduous trees. No planted trees on the plot.
2. This area was probably planted, since all areas mapped as planted were planted anywhere a man could walk.
3. Volunteers are growing on mounds.
4. Soil is poorly drained Leicester Very Stony Loam. This soil has a 2" - 5" firm layer @ 16". Digging is easy after getting through the "pan". Water coming in above & below the "pan".
5. SW aspect - lower slope on a long slope (300' +) of 0 - 5%.

PLOT #3.

1. Located in the center of a very wet swale approximately ½ acre in size. Water 2' + deep on most of the area. No data taken.

PLOT #4.

1. This plot is located on a moderately well-drained knoll. Soil is Scituate Fine Sandy Loam approximately 21" thick. This sits on a fragipan at 21". Fragipan is too hard to shovel through or dig with a post-hole digger. This knoll is oriented NE - SW, is about 600' long & 50' wide.
2. Very dense ground cover of sweet fern, bayberry, & low bush blueberry 1 - 3 feet tall. No tree species on the plot. Several clumps of grey birch can be seen on this knoll.
3. Several planted trees can be seen from the plot center looking to the NW. Those which are suppressed have been repeatedly browsed by deer.
4. This plot is at the top of a SW slope of about 20%. Slopes to Prescott Brook.

FIELD NOTES
STAND #149 - II
PLOTS ON PASTURE

S 28° W of True North - 15 chains - 2 plots @ 5 & 10 chains - begins at point "B" on Case Study Map.

Plot #1.

1. 22 planted trees on this plot. 10 are in the dominant and co-dominant crown class.
2. 3 volunteers. All deciduous. All in dominant and co-dominant crown class.
3. Stand is about 50% dense with planted trees. Deciduous trees make up another 40% of the canopy.
4. One deciduous tree off the plot takes up 20% of canopy.
5. Opening is covered with grass and polytricum moss.
6. Soil is moderately well-drained Sutton Fine Sandy Loam.
7. SW aspect - lower slope of long (300'+) slope of 5 to 10%.

Plot #2.

1. 26 volunteers - all deciduous. 19 are in dominant and co-dominant crown class.
2. 6 planted trees, all suppressed and intermediates.
3. Intermittant stream located on the east edge of plot.
4. 11 sprout clumps of alders consisting of 20 stems, 0 - 2" DBH are located near the stream, all are suppressed and were not included in the tally.
5. Soil is poorly drained Leicester Very Stony Loam.
6. SW aspect at the bottom of a long slope of 5 - 10%.

Comments.

A traverse through the center of the stand to the SW yielded two plots with the same number of volunteer stems, + or -3, it was felt that further detail of this stand was not necessary. Soils were the same as Plot #2. There were the same number of planted stens per acre, + or -4, in the same crown class as those in Plot #2.

FIELD NOTES
STANDS NO. 48 - III & 50 - III
PLOTS ON SPROUTLAND

N 64° W of True North - 5.7 chains - 3 plots @ 1.9, 3.8 & 5.7 chains.

Plot #1, Stand 48 - III.

1. 18 planted trees. 5 WP and 13 RP. 3 WP and 13 RP in dominant and co-dominant crown class.
2. 5 volunteers, 4 PP and one GB. 3 PP & GB in dominant and co-dominant crown class.
3. Soil is well-drained Charlton Fine Sandy Loam.
4. Micro-flora lacking except in openings, here it is grass and patches of polytricum moss.
5. Just off the plot, to the west, is an open area with remnants of sweet fern, bayberry, and low-bush blueberry. This has been heavily browsed. On this dry site the sweet fern and bayberry was probably too much competition for the planted trees.

Plot #1, Stand 50 - III.

1. 16 planted trees on the plot - 15 RP and 1 WP. 12 RP in dominant and co-dominant crown class.
2. 5 volunteers, 4 PP and 1 GB. 3 PP and the gray birch in dominant and co-dominant crown class.
3. Soils same as Plot #1, Stand 48 - III.
4. Micro-flora same as Plot #1, Stand 48 - III.
5. SW & W of the plot there are no planted trees. Woody vegetation consists of sweet fern, bayberry, low-bush blueberry, and some grasses. Not as dense as Plot #3, Stand 146 - II, Case Study Area I.

Plot # 2, Stand 50 - III.

1. Canopy completely taken up by volunteer hardwoods and pitch pine. A few small openings but 90% of the canopy is closed.
2. No planted trees living. Two dead RP stems found off the plot in this general area. Scattered WP persist off the plot.
3. Understory has scattered high and low-bush blueberry, bracken fern and crass -- not dense.
4. Soil is a moderately well-drained Sutton Fine Sandy Loam over a water washed till.

FIELD NOTES
STAND NO. 44 - III
PLOTS ON ARABLE LAND

N 23°30' E of True North - 5.7 chains - 3 plots @ 1.9, 3.8 and 5.7 chains.

Plot #1.

1. White pine makes up 85% of the canopy. Appears that WP weevil prevented intermediates from becoming dominants and co-dominants.
2. Very few volunteer trees.
3. Micro-flora in understory lacking. Just 3 suppressed high-bush blueberries.
4. Soil is very poorly drained Whitman Muck.

Plot #2.

1. Same as Plot #1 except north side of the plot is the edge of a deer yard.
2. This area was obviously cultivated just prior to the time of planting.

Plot #3.

1. Same as Plot #1 except there is some RP in the canopy.
2. Plot was mapped.

FIELD NOTES

STAND #34 - III

S 27°E of True North and N 70°E - 6 plots running North and South and, East and West through the center of the stand.

Plot #1.

1. Planted trees take up 95% of canopy. WP weevil has been active in this stand. Probably has reduced the average height of the stand.
2. No micro flora in the understory.
3. Soil - well-drained Charlton fine sandy loam.

Plot #2

1. Same as plot #1

Plot #3

1. Same as plot #1

Plot #4

1. This was pasture land. Does support a few more volunteers per acre.
2. Otherwise, all the same as plot #1.

Plot #5

1. Same as plot #4

Plot #6

1. Same as plot #4

FIELD NOTES

Number of Stems Per Acre

Percentage of Establishment	No. Trees Per Fifth Acre Plot
Plot #1 - 25%	8
Plot #2 - 25%	10
Plot #3 - 25%	12
Plot #4 - 55%	14
Plot #5 - 55%	20
Plot #6 - 55%	16

Plots were scattered in various stands of 25 and 55% crown closures in compartments II and III.

HARVARD FOREST RECORDS

Stand: 146-II

By: Dodge and Gould

Table I Appendix B

Date: May 1960

Plot #1 - 1/25 Acre

Volunteer Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 12'	Age @ 16'	Age @ 20'	Age @ 24'	Age @ 28'	Total Age	Total Height	Crown Class	Ring Count @ 4'
2	RM	5"	8	14	16	18	20	22		29	32'	D	19
3	RM	3"	11	16	18	21	24			31	30'	CD	19
7	ALD	2"	Butt rot prevents accurate ring count								24'	CD	
7	ALD	2"	" " "			"	"	"			24'	CD	
7	ALD	2"	" " "			"	"	"			24'	CD	
7	ALD	2"	" " "			"	"	"			20'	I	
14	RM	2"	9	18						28	14'	S	19
14	RM	2"	12	16	18	22				31	27'	CD	19
21	RM	4"	8	11	15	18	21	23		29	30'	D	20
22	RM	3"	11	15	18	20	23	27		30	31'	D	19
23	RM	2"	6	12	15	16	18			24	28'	D	18
25	RM	4"	9	16	19	22	24			31	30'	D	22
26	WA	4"	13	15	17	19	21	22	24	28	35'	D	15
27	RM	3"	12	17	19	22				32	26'	S	20
28	RM	3"	12	15	19	24				32	28'	CD	20
29	RM	3"	11	15	18	20	23	25		30	31'	D	19
33	CH	2"	9	13	13	13				23	16'	S	14
35	RM	2"	8	12	15	18	19	21		26	31'	CD	18
36	ALD	3"	5	9	11	15				23	26'	CD	18
37	ALD	3"	Butt rot prevents accurate ring count								26'	CD	
38	ALD	3"	" " "			"	"	"			20'	I	
41	WP	7"	Did not dissect							23	31'	D	
42	CH	3"	9	15	16	17	20			26	28'	D	18
44	ALD	4"	7	8	11	13				23	28'	D	21
45	RM	5"	11	15	19	21	25			32	32'	D	22
47	RM	5"	11	15	19	22	22			32	32'	D	21

RM= red maple
WA= white ash
CH= pin cherry
WP= white pine
ALD= common alder

HARVARD FOREST RECORDS

Stand: 146-II

Table II Appendix B

By: Dodge and Gould

Date: May 1960

Plot #1 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Age @ 32'	Total Age	Total Height	Crown Class	Crown Length	Crown Radius
1	NS	3"	10	15	28			28	16'	S	9'	5'
4	NS	3"						28				
5	NS	1"	14	23				28	10'	S	6'	3'
6	NS	3"	13	19	28			28	16'	S	13'	4'
8	NS	4"						28		S		
9	NS	4"						28		S		
10	NS	4"						28		CD		
11	NS	6"						28		D		
12	NS	4"						28		CD		
13	NS	2"						28		S		
15	NS	4"						28		D		
16	NS	2"						28		S		
17	NS	7"	8	15	22	26		28	29'	D	23'	8'
18	L	5"						26		CD		
19	NS	4"	10	18	21	26		28	29'	I	22'	4'
20	NS	5"	8	12		23	26	28	35'	D	26'	4'
24	NS	3"	8	12	25			28	20'	S	13'	5'
30	NS	4"	9	13	21	25	28	28	32'	I	23'	6'
31	NS	5"	10	13	21	23	28	28	33'	CD	28'	5'
32	NS	7"	9	13	21	25	28	28	32'	D	25'	8'
34	NS	4"	8	13	21	24	28	28	32'	CD	19'	5'
39	NS	1"	15					28	7'	S	3'	3'
40	NS	2"						28		S		
43	NS	1"	17					28	8'	S	4'	3'
46	L	5"						26		I.		

NS= Norway spruce
L= European larch

HARVARD FOREST RECORDS

Stand: 146-II

Table III Appendix B

By: Dodge

Date: June 1960

Plot #2 - 1/25 Acre

Volunteer Species

Species	DBH	Total Height	Crown Class	Crown Length	Ring Count @ 4'
RM	7"		D		
RM	4"		I		
WA	5"	45	D	24	19
GB	6"	48	D	21	32
GB	4"	41	D	23	29
RM	2"		S		
RM	2"		S		
RM	2"		S		
RM	3"	30	I	10	20
WA	16"		D		
GB	5"		CD		
RM	2"		I		
RM	2"		S		
WA	3"		I		
RM	6"		D		
RM	3"		S		
GB	4"		CD		
RM	2"		S		
RM	2"		S		
WA	9"		D		
RM	4"		CD		
RM	4"	37	CD	23	22
RM	4"	29	CD	20	21
RM	3"		I		
RM	2"		S		
RM	5"	40	D	20	20
RM	5"	38	CD	21	24
RM	5"		CD		
WA	8"		D		
CH	5"		D		
RM	4"		CD		
WA	3"		CD		
RM	4"		I		
RM	4"		CD		

RM= red maple
GB= grey birch
WA= white ash
CH= pin cherry

HARVARD FOREST RECORDS

Stand: Stand: 146-II Table IV Appendix B By: Dodge

Date: June 1960

Plots #5 and #6

Planted Species

Plot #5 - 1/25 Acre

Tree #	Species	DBH	Total Age	Total Height	Crown Class	Crown Length	Crown Radius
1	NS	3"	28		S		
2	NS	9"	28		D		
3	NS	5"	28		CD		
4	NS	7"	28		CD		
5	NS	8"	28		D		
6	NS	6"	28		CD		
7	NS	4"	28		I		
8	NS	8"	28		D		
9	NS	6"	28		CD		
10	NS	8"	28		D		
11	NS	7"	28		D		
12	NS	7"	28		D		
13	NS	4"	28		I		
14	NS	8"	28	45'	D	35'	5'
15	NS	7"	28		D		
16	NS	7"	28		D		
17	NS	5"	28		I		
18	NS	3"	28		S		
19	NS	7"	28		CD		
20	NS	5"	28		CD		
21	NS	10"	28		D		
22	NS	5"	28		I		
23	NS	9"	28	46'	D	36'	7'
24	NS	6"	28	34'	CD	25'	5'
25	NS	6"	28		CD		
26	NS	6"	28		CD		
27	NS	6"	28		CD		

Plot #6 - 1/25 Acre

Tree #	Species	DBH	Total Age	Total Height	Crown Class	Crown Length	Crown Radius
1	NS	9"	28	39'	D	33'	10'
2	L	5"	26		I		
3	NS	8"	28	41'	D	35'	10'
4	NS	5"	28		I		
5	NS	9"	28		D		
6	NS	9"	28		D		
7	NS	11"	28		D		
8	NS	10"	28	34'	D	30'	12'

NS= Norway spruce

L= European larch

HARVARD FOREST RECORDS

Stand: Stand: 146-II Table V Appendix B By: Dodge

Date: June 1960

Plots #7 and #8

Planted Species

Plot #7 - 1/25 Acre

Tree #	Species	DBH	Total Age	Total Height	Crown Class	Crown Length	Crown Radius
1	NS	6"	28		CD		
2	NS	7"	28		D		
3	NS	5"	28		CD		
4	NS	9"	28		D		
5	NS	4"	28		I		
6	NS	6"	28		CD		
7	NS	5"	28		CD		
8	NS	8"	28		D		
9	NS	6"	28		D		
10	NS	8"	28		D		
11	NS	7"	28		D		
12	NS	8"	28		D		
13	L	8"	26		CD		
14	NS	6"	28		CD		
15	NS	7"	28		D		
16	NS	7"	28		CD		
17	NS	7"	28		CD	Double Crown	
18	NS	9"	28		D		
19	NS	5"	28		I		
20	NS	7"	28		D		
21	L	4"	26		S		

Plot #8 - 1/25 Acre

Tree #	Species	DBH	Total Age	Total Height	Crown Class	Crown Length	Crown Radius
1	NS	11"	28		D		
2	NS	9"	28		D		
3	NS	10"	28		D		
4	NS	4"	28		D		
5	NS	5"	28	26'	I	20'	7'
6	NS	6"	28		CD		
7	NS	7"	28		CD		
8	NS	8"	28		D		
9	L	4"	26		I		
10	NS	10"	28	42'	D	36'	10'
11	NS	8"	28	35'	D	30'	8'

NS= Norway spruce

L= European larch

HARVARD FOREST RECORDS

Stand: Stand 149-II Table VI Appendix B By: Dodge

Date: June 1960

Plot #1 - 1/25 Acre

Volunteer Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Age @ 32'	Total Age	Total Height	Crown Class	Crown Radius	Ring Count @ 4'	Crown Length
9	RM	3"								CD		15	
13	CH	6"								D		24	
14	CH	3"								D		24	

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Age @ 32'	Total Age	Total Height	Crown Class	Crown Radius	Ring Count @ 4'	Crown Length
1	NS	4"						28		I			
2	NS	6"						28		CD			
3	NS	3"	8	13	14	21		28	29'	I	5'		20'
4	NS	8"						28		D			
5	NS	6"						28		CD			
6	NS	5"						28		CD			
7	NS	5"						28		I			
8	NS	7"	7	12	15	17		28	40'	D	8'		31'
10	NS	5"	10	12	13	17		28	34'	I	5'		28'
11	NS	5"						28		CD			
12	NS	6"						28		CD			
15	NS	4"						28		I			
16	NS	8"						28		D			
17	NS	2"						28		S			
18	NS	4"						28		I			
19	NS	5"						28		CD			
20	NS	8"						28		D			
21	NS	3"						28		S			
22	NS	6"						28		I			
23	NS	3"						28		S			
24	NS	3"						28		I			
25	NS	1"	13	20				28	10'	S	3'		8'

RM= red maple

CH= pin cherry

NS= Norway spruce

HARVARD FOREST RECORDS

Stand: Stand 149-II Table VII Appendix B By: Dodge

Date: June 1960

Plot #2 - 1/25 Acre

Volunteer Species

Tree #	Species	DBH	Total Age	Crown Class
1	RM	5"		D
2	RM	5"		D
3	RM	2"		I
4	RM	5"		D
5	RM	5"		D
6	BB	3"		D
7	BB	3"		D
8	BB	3"		D
9	GB	3"		I
12	GB	3"		I
13	CH	5"		D
17	RO	2"		I
19	BB	5"		D
20	BB	3"		CD
21	GB	5"		CD
22	GB	5"		CD
23	BB	2"		I
24	BB	2"		I
25	BB	3"		CD
26	BB	3"		CD
27	BB	4"		I
28	RM	7"		D
29	RM	3"		CD
30	BB	4"		CD
31	BB	3"		CD
32	RM	4"		CD

Planted Species

10	NS	1"	28	S
11	NS	4"	28	I
14	NS	3"	28	S
15	NS	4"	28	I
16	NS	5"	28	I
18	NS	1"	28	S

RM= red maple
BB= black birch
GB= grey birch
CH= pin cherry
RO= red oak
NS= Norway spruce

HARVARD FOREST RECORDS

Stand: Stand 44-III Table VIII Appendix B By: Dodge

Date: June 16, 1960

Plot #1 - 1/25 Acre

Planted Trees

Tree #	Species	DBH	Age @ 4'	Crown Class	Ring Count @ 4'
1	WP	4"	6	I	
2	WP	2"	9	S	
3	WP	6"	6	D	
4	WP	6"	5	D	
5	WP	6"	5	D	
6	WP	5"	5	CD	
7	WP	4"	6	I	
8	WP	6"	5	D	
9	WP	4"	6	D	
10	WP	3"	9	I	
11	WP	4"	8	I	
12	WP	3"	7	I	
13	WP	5"	5	D	
14	WP	4"	6	CD	
15	WP	3"	6	S	
16	WP	2"	10	S	
17	WP	2"	8	S	
28	WP	3"	8	S	
29	WP	2"	7	S	
30	WP	5"	5	CD	
31	WP	3"	5	I	
32	WP	4"	5	I	
33	WP	4"	5	I	
34	WP	3"	6	S	
36	WP	6"	5	D	
37	WP	6"	5	D	
38	WP	4"	6	CD	
39	WP	4"	7	I	
40	WP	3"	7	I	
41	WP	4"	6	S	
45	WP	7"	4	D	
46	WP	6"	5	D	
47	WP	5"	5	I	
48	WP	4"	5	I	
49	WP	3"	5	I	
50	WP	4"	5	I	
51	WP	3"	6	S	

WP= white pine

HARVARD FOREST RECORDS

Stand: Stand 44-III Table IX Appendix B Continued By: Dodge

Date: June 16, 1960

Plot #1 - 1/25 Acre

Volunteer Species

Tree #	Species	DBH	Crown Class	Ring Count @ 4'
18	GB	3"	D	
19	ASP	3"	CD	
20	ASP	3"	CD	15
21	ASP	3"	CD	15
22	ASP	4"	D	15
23	ASP	4"	D	15
24	ASP	4"	CD	15
25	GB	3"	CD	
26	GB	2"	S	
27	ASP	4"	D	17
35	RM	5"	D	
42	GB	5"	D	20
43	GB	5"	D	20
44	GB	2"	I	

GB= grey birch
ASP= aspen
RM= red maple

HARVARD FOREST RECORDS

Stand: Stand 44-III Table X Appendix B By: Dodge

Date: June 16, 1960

Plot #2 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Crown Class	Ring Count @ 4'
1	WP	3"	5	CD	
7	WP	5"	6	CD	
8	WP	3"	7	S	
9	WP	4"	8	D	
10	WP	3"	7	I	
13	WP	6"	5	D	
14	WP	4"	7	CD	
15	WP	4"	5	I	
17	WP	4"	5	S	
18	WP	6"	6	CD	
19	WP	3"	6	I	
20	WP	4"	5	S	
22	WP	7"	5	D	
23	WP	4"	6	I	
24	WP	4"	6	I	
25	WP	6"	5	D	
26	WP	4"	9	D	
27	WP	5"	5	CD	
29	WP	3"	7	I	
30	WP	4"	6	D	
31	WP	3"	8	CD	
32	WP	3"	8	CD	

WP= white pine

Volunteer Species

2	GB	4"		D	
3	GB	4"		D	26
4	ASP	3"		D	
5	GB	3"		D	
6	ASP	3"		D	15
11	ASP	3"		D	
12	ASP	3"		CD	17
16	GB	3"		D	16
21	CH	4"		D	18
28	RM	5"		D	

GB= grey birch

ASP= aspen

CH= pin cherry

RM= red maple

HARVARD FOREST RECORDS

Stand: Stand 44-III Table XI Appendix B By: Dodge

Date: June 1960

Plot #3 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Total Age	Total Height	Crown Class
1	WP	2"	7	9	12	18	27		S
2	RP	6"	6	10	15	24	27		D
3	RP	6"	5				27		CD
4	RP	5"	5	9	15	26	27		CD
5	RP	6"	5				27		D
6	RP	6"	5				27		D
7	RP	3"	8				27		I
8	RP	3"	6				27		I
10	WP	2"	7				27		S
11	RP	7"	6				27		D
12	RP	3"	6				27		S
13	RP	5"	6				27		CD
14	RP	5"	5				27		CD
15	RP	5"	5				27		CD
18	RP	6"	5				27		D
19	RP	5"	6				27		I
20	RP	2"	6				27		S
21	RP	3"	6	8	14	18	27		I
22	RP	5"	6				27		CD
23	WP	3"	9				27		I
24	WP	5"	6				27		CD
26	RP	8"	4	7	13	26	27		D
27	WP	3"	6				27		I
29	WP	3"	7				27		S
30	WP	4"	5				27		CD
31	WP	6"	6				27		CD
32	WP	4"	4				27		I
34	WP	5"	5	9	16	22	27		CD
35	RP	5"	5				27		D
38	WP	3"	11				27		S
39	WP	3"	7				27		I

RP= red pine

WP= white pine

HARVARD FOREST RECORDS

Stand: Stand 44-III Table XII Appendix B By: Dodge

Date: June 1960

Plot #3 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Total Age	Total Height	Crown Class
40	WP	4"	5				27		CD
41	WP	4"	4	6	8	24	27		CD
42	WP	6"	4				27		D
43	RP	3"	5	7	9	20	27		S
44	RP	3	6				27		S
47	RP	7"	5				27		D
48	RP	5"	5				27		CD
49	RP	5"	4				27		CD
50	RP	5"	4	8	14	24	27		CD
51	WP	6"	5				27		D

Volunteer Species

9	RM	2"							CD
16	RM	5"							D
17	RM	5"							D
25	RM	5"							D
28	GB	4"							D
33	GB	2"							CD
36	GB	3"							CD
37	RM	3"							D
45	GB	3"							D
46	GB	3"							D

RP= red pine
WP= white pine
RM= red maple
GB= grey birch

HARVARD FOREST RECORDS

Stand: Stand 48-III

Table XIII Appendix B

By: Dodge

Date: June 1960

Plot #1 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Total Age	Total Height	Crown Class
1	RP	6"	6				27	36'	CD
2	RP	8"	6	9	15		27		D
3	RP	8"	6				27		D
4	RP	9"	6	8	15	20	27	36'	D
5	RP	6"	6	8	14	17	27	34'	CD
6	RP	6"	6				27		CD
7	WP	4"	8	12	18		27	23'	I
8	WP	8"	6	9	16		27	33'	D
9	RP	7"	6				27		CD
10	RP	6"	6				27		CD
11	RP	8"	6				27		D
12	RP	7"	6				27		D
13	RP	7"	5				27		D
15	RP	8"	6				27		CD
16	WP	11"	4				27		D
17	WP	4"	6				27		S
18	WP	6"	6				27		CD
19	RP	6"	6				27		D

Volunteer Species

14	CH	5"							CD

RP= red pine

WP= white pine

CH= pin cherry

HARVARD FOREST RECORDS

Stand: Stand 50-III Table XIV Appendix B By: Dodge

Date: June 1960

Plot #1 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Age @ 32'	Total Age	Total Height	Crown Class	Ring Count @ 4'
1	RP	8"	5	7	13	18		27	35'	D	
2	RP	8"						27		D	
3	RP	7"	5	7	13	19		27	30'	CD	
4	RP	10"	6					27		D	
5	RP	9"	5					27		D	
6	RP	9"	5					27		D	
7	RP	8"	5					27		D	
8	RP	5"	5					27		CD	
10	RP	5"	6					27		CD	
11	RP	4"	6	6	8	16		27	21'	I	
12	RP	4"	7	9	15			27	19'	S	
14	RP	6"	6	8	13	18		27	30'	CD	
16	WP	3"	9					27		S	
18	RP	4"	5					27		I	
19	RP	7"	5					27		D	
20	RP	6"	6					27		D	

Volunteer Species

9	PP	7"								CD	
13	PP	10"								D	
15	PP	6"								D	
17	PP	2"								S	
21	GB	3"								CD	15

RP= red pine
WP= white pine
PP= pitch pine
GB= grey birch

HARVARD FOREST RECORDS

Stand: Stand 50-III Table XV Appendix B **By:** Dodge

Date: June 1960

Plot #2 - 1/25 Acre

Volunteer Species Not Dissected

Tree #	Species	DBH	Crown Class
1	PP	7"	D
2	GB	2"	S
3	GB	3"	CD
4	GB	3"	CD
5	RM	3"	CD
6	RM	4"	D
7	GB	3"	CD
8	GB	4"	CD
9	GB	3"	I
12	RM	5"	CD
21	GB	3"	I
22	GB	3"	I
23	GB	3"	I
24	CH	3"	I
25	GB	5"	D
26	GB	5"	D
27	GB	3"	CD
28	GB	3"	CD
29	GB	3"	I
30	GB	2"	I
31	GB	2"	CD
32	GB	3"	D
33	GB	3"	I
34	GB	3"	D
35	GB	3"	I
36	GB	2"	I
37	GB	3"	CD
38	GB	3"	D
41	PP	5"	CD
42	GB	3"	CD
48	GB	3"	I

PP= pitch pine
GB= grey birch
RM= red maple
CH= pin cherry

HARVARD FOREST RECORDS

Stand: Stand 50-III Table XVI Appendix B **By:** Dodge and Bulkarowski

Date: May 1960

Plot #2 - 1/25 Acre

Dissected Volunteer Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 12'	Age @ 16'	Age @ 20'	Age @ 24'	Age @ 28'	Total Age	Total Height	Crown Class	Ring Count @ 4'
10	GB	2"	2	4	9	9				16	20'	S	14
11	RM	6"	5	6	7	9	13	16	17	29	43'	D	24
13	RM	5"	2	4	5	7	8	12	15	25	41'	CD	23
14	RM	4"	4	6	6	8	13	14	15	25	35'	CD	21
15	RM	2"		1	3	4				11	19'	S	11
16	RM	4"	2	4	6	8	10	12	13	25	39'	CD	23
17	RM	2"	1	6	7	8	10			16	25'	S	15
18	RM	2"	6	7	8	10	12			24	28'	S	18
19	RM	3"	2	6	7	9	10	14	16	25	33'	I	23
20	RM	5"	2	4	6	7	8	11	13	24	40'	CD	22
39	GB	4"	4	6	7	11	14	18	20	26	34'	D	21
40	GB	3"	8		9	15	19			24	27'	CD	16
43	CH	4"	4	9	12	14	16	19		24	32'	CD	20
44	WB	2"	5	11	12					22	22'	S	17
45	WB	6"	5	9		10	13	17	20	27	36'	D	22
46	WB	5"	1	3	7	8		11	13	25	41'	D	24
47	WB	3"	3	7	9	11	13		15	22	36'	I	19

Tree #	Age @ 32'	Age @ 36'	Length of Crown
10			8'
11	20	23	21'
13	16	18	25'
14			17'
15			8'
16	18		20'
17			14'
18			14'
19			14'
20	15		26'
39			24'
40			17'
43			18'
44			15'
45			25'
46	17	19	23'
47			25'

RM= red maple
GB= grey birch
WB= white birch
CH= pin cherry

HARVARD FOREST RECORDS

Stand: Stand 34-III Table XVII Appendix B By: Dodge

Date: June 1960

Plot #1

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 8'	Age @ 16'	Age @ 24'	Total Age	Total Height	Crown Class
1	WP	5"	5	8	16	22	27		I
2	WP	6"	5				27		D
3	WP	5"	5				27		D
4	WP	5"	6				27		CD
5	WP	3"	6				27		I
6	WP	6"	4				27		D
7	WP	6"	5				27		D
8	WP	6"	4	8	16	23	27		D
9	WP	6"	5				27		CD
10	WP	3"	5				27		CD
11	WP	6"	6				27		D
12	WP	5"	5				27		CD
13	WP	5"	6				27		I
14	WP	4"	6				27		I
15	WP	6"	5	7	14	23	27		D
16	WP	5"	5	7	14	24	27	26'	CD
17	WP	5"	5				27		CD
18	WP	5"	6				27		CD
19	WP	2"	8				27		S
20	WP	7"	5				27		D
21	WP	3"	6				27		S
22	WP	5"	7				27		CD
23	WP	4"	7				27		I
24	WP	4"	6				27		CD
25	WP	3"	6				27		I
26	WP	7"	4				27		D
27	WP	7"	5				27		D
28	WP	7"	5				27		D
29	WP	5"	4				27		CD
30	WP	6"	4				27		D
31	WP	7"	5	7	16	23	27	31'	D
32	WP	4"	4				27		I
33	WP	6"	5				27		D
34	WP	3"	4				27		I
35	WP	4"	6				27		S
36	WP	3"	6				27		I
37	WP	3"	5				27		I
38	WP	5"	6				27		CD
39	WP	3"	6	8	16		27	24'	CD
40	WP	7"	4				27		D

WP= white pine

HARVARD FOREST RECORDS

Stand: Stand 34-III Table XVIII Appendix B Continued By: Dodge

Date: June 1960

Plot #1

Planted Species

Tree #	Species	DBH	Age @ 4'	Age @ 16'	Age @ 24'	Total Age	Total Height	Crown Class	Ring Count @ 4'
41	WP	4"	5			27	24'	CD	
42	WP	3"	5			27		S	
43	WP	4"	6			27		I	
47	WP	3"	5			27		S	
48	WP	5"	7			27		CD	
49	WP	4"	5			27		I	
50	WP	5"	5			27		I	
53	WP	7"	4			27		D	

Volunteer Species

44	ASP	3"						CD	15
45	ASP	3"						CD	
46	ASP	3"						CD	15
51	A	3"						CD	
52	A	2"						CD	17

WP= white pine

ASP= aspen

A= white ash

HARVARD FOREST RECORDS

Stand: Stand 34-III Table XIX Appendix B By: Dodge

Date: June 1960

Plot # 2

Planted Species

Tree #	Species	DBH	Age @ 4'	Crown Class	Tree #	Species	DBH	Age @ 4'	Crown Class
1	WP	6"	5	CD	2	WP	7"	4	D
3	WP	4"	6	I	4	WP	5"	6	I
5	WP	6"	5	D	6	WP	5"	5	CD
7	WP	4"	6	I	8	WP	6"	6	D
9	WP	6"	5	CD	10	WP	4"	6	I
11	WP	3"	5	S	12	WP	8"	5	D
13	WP	7"	5	D	14	WP	4"	5	I
15	WP	6"	5	D	16	WP	4"	6	I
17	WP	6"	6	CD	18	WP	5"	5	CD
19	WP	6"	6	CD	20	WP	4"	6	I
21	WP	4"	6	I	22	WP	7"	5	D
23	WP	5"	5	CD	24	WP	8"	4	D
25	WP	5"	5	CD	26	WP	6"	5	D
27	WP	5"	6	CD	28	WP	7"	5	D
29	WP	3"	5	S	30	WP	5"	5	CD
31	WP	4"	5	I	32	WP	6"	5	D
33	WP	7"	5	D	34	WP	5"	5	CD
35	WP	7"	4	D	36	WP	5"	5	D
37	WP	4"	5	S	38	WP	3"	5	S
39	WP	5"	5	CD	40	WP	6"	5	D
41	WP	7"	4	D					

WP= white pine

HARVARD FOREST RECORDS

Stand: Stand 34- III Table XX Appendix B **By:** Dodge

Date: June 1960

Plot #3 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Crown Class	Tree #	Species	DBH	Age @ 4'	Crown Class
1	WP	7"	5	D	2	WP	6"	5	D
3	WP	3"	6	S	4	WP	7"	5	D
5	WP	4"	6	I	6	WP	5"	5	CD
7	WP	5"	5	CD	8	WP	6"	6	CD
9	WP	4"	8	I	10	WP	6"	5	D
11	WP	7"	5	D	12	WP	4"	5	I
13	WP	5"	4	CD	14	WP	6"	5	CD
15	WP	7"	5	D	16	WP	5"	5	CD
17	WP	5"	5	CD	18	WP	7"	4	D
19	WP	5"	4	D	20	WP	6"	5	D
21	WP	5"	4	CD	22	WP	5"	4	D
23	WP	5"	5	CD	24	WP	5"	5	CD
25	WP	5"	5	CD	26	WP	7"	4	D
27	WP	6"	4	D	28	WP	6"	5	D
29	WP	6"	4	CD	30	WP	5"	5	CD
31	WP	6"	5	D	32	WP	5"	5	CD
33	WP	4"	5	I	34	WP	6"	5	D
35	WP	5"	4	D	36	WP	6"	4	D
37	WP	7"	5	D	38	WP	5"	5	CD
39	WP	5"	6	I	40	WP	4"	5	I
41	WP	7"	5	D					

WP= white pine

HARVARD FOREST RECORDS

Stand: Stand 34-III Table XXI Appendix B By: Dodge and Davidson

Date: June 1960

Plot #4 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Crown Class	Tree #	Species	DBH	Age @ 4'	Crown Class	Ring Count @ 4'
1	RP	4"	5	CD	2	RP	4"	6	CD	
3	WP	3"	6	S	4	RP	6"	6	D	
5	RP	6"	5	D	6	RP	4"	5	CD	
7	RP	6"	5	D	8	RP	6"	5	CD	
9	RP	6"	5	D	10	RP	4"	6	D	
11	RP	5"	5	CD	12	RP	4"	6	CD	
13	WP	5"	6	CD	14	RP	5"	7	CD	
15	RP	3"	7	I	16	RP	4"	6	CD	
17	WP	3"	6	I	18	WP	6"	4	CD	
19	RP	6"	5	CD	20	RP	4"	6	I	
21	RP	3"	6	S	22	RP	4"	6	I	
23	RP	5"	6	CD	24	RP	6"	4	D	
25	WP	4"	5	CD	26	WP	6"	5	D	
27	RP	5"	5	CD	28	RP	6"	5	D	
29	WP	4"	5	I	30	WP	4"	6	CD	
31	RP	4"	6	I	32	RP	6"	5	D	
33	RP	6"	6	D	34	RP	3"	7	I	
35	RP	7"	5	D	36	WP	3"	7	S	
37	RP	4"	5	I	38	RP	6"	5	D	
39	WP	5"	5	CD	40	WP	4"	6	I	
41	WP	5"	5	CD	42	WP	6"	4	D	
43	RP	5"	5	CD	44	RP	4"	6	CD	
45	RP	5"	6	CD	46	WP	5"	5	I	
48	WP	3"	7	S	49	RP	3"	6	S	
50	WP	7"	4	D	51	RP	5"	6	D	
52	RP	6"	6	D	53	WP	3"	4	S	

Volunteer Species

					47	CH	5"		D	17

HARVARD FOREST RECORDS

Stand: Stand 34-III Table XXII Appendix B By: Dodge and Davidson

Date: June 1960

Plot #5 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Crown Class	Tree #	Species	DBH	Age @ 4'	Crown Class	Ring Count @ 4'
1	RP	6"	4	D	2	RP	3"	6	I	
3	RP	4"	5	CD	4	RP	6"	5	D	
5	RP	5"	6	CD	6	RP	6"	5	CD	
7	RP	6"	5	D	8	RP	6"	5	D	
9	RP	6"	5	CD	10	RP	4"	5	I	
11	RP	4"	5	I	12	RP	3"	7	S	
13	RP	8"	4	D	14	RP	6"	5	CD	
15	RP	6"	5	D	16	RP	6"	5	D	
17	RP	5"	5	CD	18	RP	5"	5	CD	
19	RP	3"	6	I	20	RP	5"	4	CD	
21	RP	5"	4	CD	22	RP	4"	6	I	
23	RP	6"	5	D	24	RP	5"	5	CD	
25	RP	4"	6	CD	26	RP	6"	5	D	
27	RP	4"	5	CD	28	RP	6"	5	D	
30	RP	1"	9	S	31	RP	6"	5	D	
32	RP	5"	5	D	33	RP	5"	5	CD	
34	RP	4"	5	I	35	RP	3"	5	S	
36	RP	5"	6	CD	39	WP	6"	5	D	
40	RP	4"	4	CD	41	RP	5"	4	CD	
42	RP	5"	4	D	43	RP	6"	4	D	
44	WP	5"	5	CD	45	RP	5"	4	D	
46	RP	4"	6	I	47	RP	6"	6	D	
48	RP	3"	7	I	49	RP	4"	6	CD	
50	WP	3"	7	I						

Volunteer Species

29	CH	4"		D	17
37	GB	2"		CD	19
38	GB	3"		D	19

RP= red pine

WP= white pine

CH= pin cherry

GB= grey birch

HARVARD FOREST RECORDS

Stand: Stand 34-III Table XXIII Appendix B By: Dodge and Davidson

Date: June 1960

Plot #6 - 1/25 Acre

Planted Species

Tree #	Species	DBH	Age @ 4'	Crown Class	Ring Count @ 4'	Tree #	Species	DBH	Age @ 4'	Crown Class
1	RP	5"	5	CD		2	RP	3"	7	S
3	RP	6"	7	D		4	RP	4"	7	CD
5	RP	5"	7	CD		6	RP	4"	6	CD
7	RP	4"	8	I		8	RP	4"	7	CD
9	RP	6"	4	D		10	RP	6"	6	D
11	RP	4"	7	CD		12	RP	5"	6	D
13	RP	4"	7	I		14	RP	4"	7	I
15	RP	5"	5	D		16	RP	3"	6	S
17	RP	4"	5	CD		18	RP	5"	5	CD
19	RP	6"	5	D		20	RP	4"	5	I
21	RP	7"	6	D		23	RP	7"	5	D
24	RP	4"	6	I		26	RP	7"	5	D
27	RP	7"	5	D		28	RP	4"	5	I
30	RP	5"	6	CD		31	RP	6"	5	D
33	RP	4"	4	CD		34	RP	4"	5	CD
35	RP	2"	8	S		36	RP	4"	8	I
37	RP	4"	8	CD		38	RP	5"	5	D

Volunteer Species

Tree #	Species	DBH	Crown Class	Ring Count @ 4'
22	CH	4"	D	17
25	CH	2"	I	
29	CH	4"	D	14
32	CH	3"	D	17

RP= red pine

CH= pin cherry

FIGURE I

Relationship of Total Height to Age of Norway Spruce Planted on Case Study Area I, Prescott Penninsula.

This relationship compares favorably with Expected Height Growth According to Age, illustrated by Rudolph (1950), Pp. 126. Data Taken from Plots No. 1, 5, 6, and 8, Stand No. 146 - II and Plot No. 1, Stand No. 149 - II.

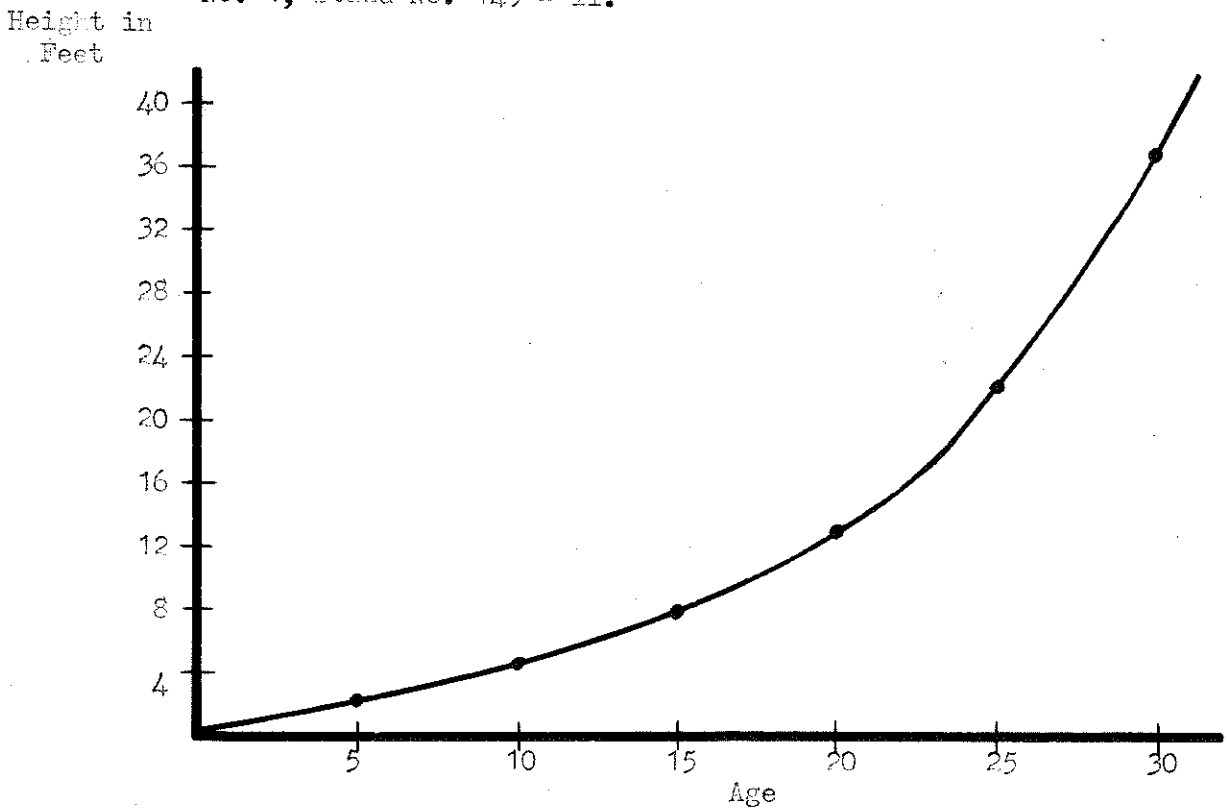


FIGURE II

Relationship of Total Height to Age of Volunteer Deciduous Species on The Prescott Penninsula.

Data includes measurements from red maple, white ash, white birch, black birch, gray birch, pin cherry and red oak. This relationship compares favorably with data produced by Cline and Lockard (1995), Pp. 23 and 27. Data taken from Plot No. 1, Stand 146 - II and Plot No. 2, Stand 50 - III.

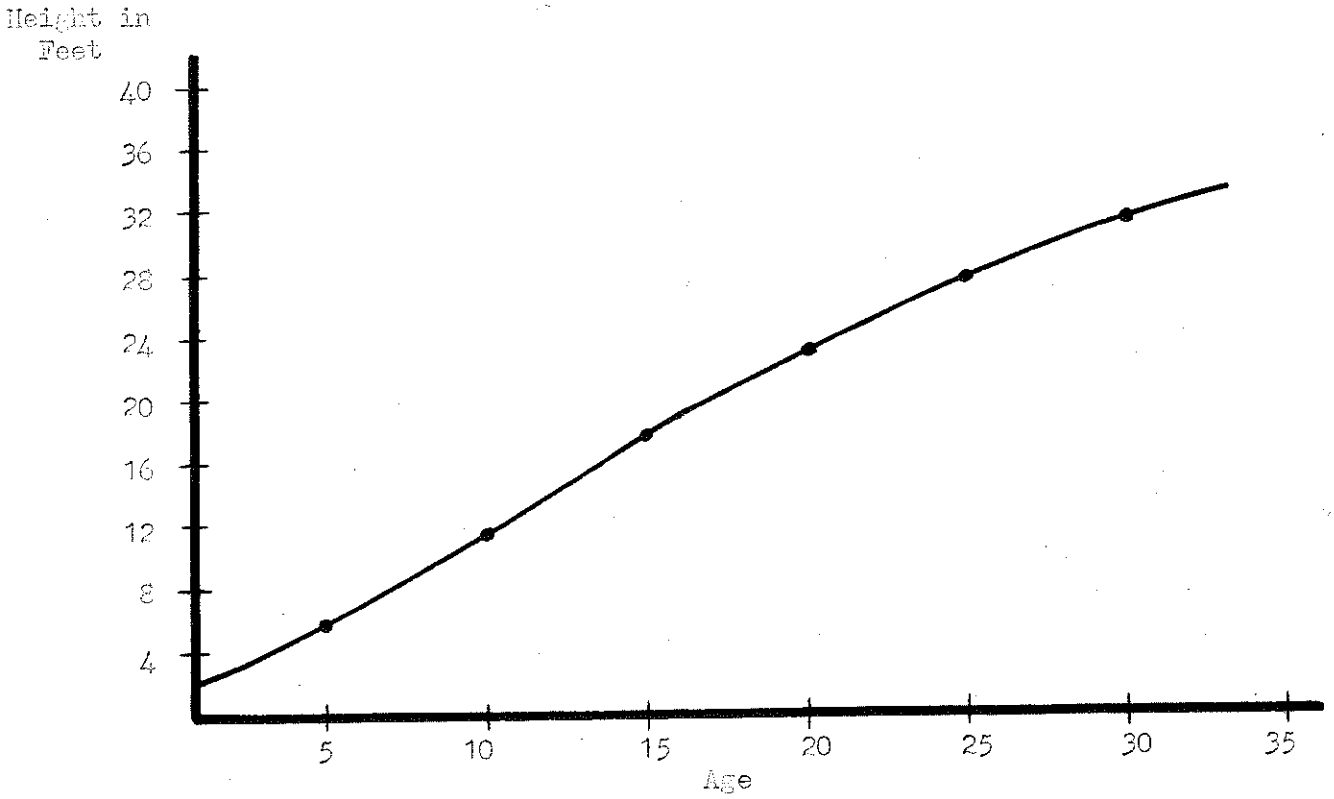


FIGURE III

Height Growth of Suppressed Norway Spruce.

Relationship of total height to age of underplanted Norway spruce, Case Study Area I, Prescott Penninsula. Data taken from measurements on Plot No. 1, Stand 146 - II and Plot No. 1, Stand 149 - II.

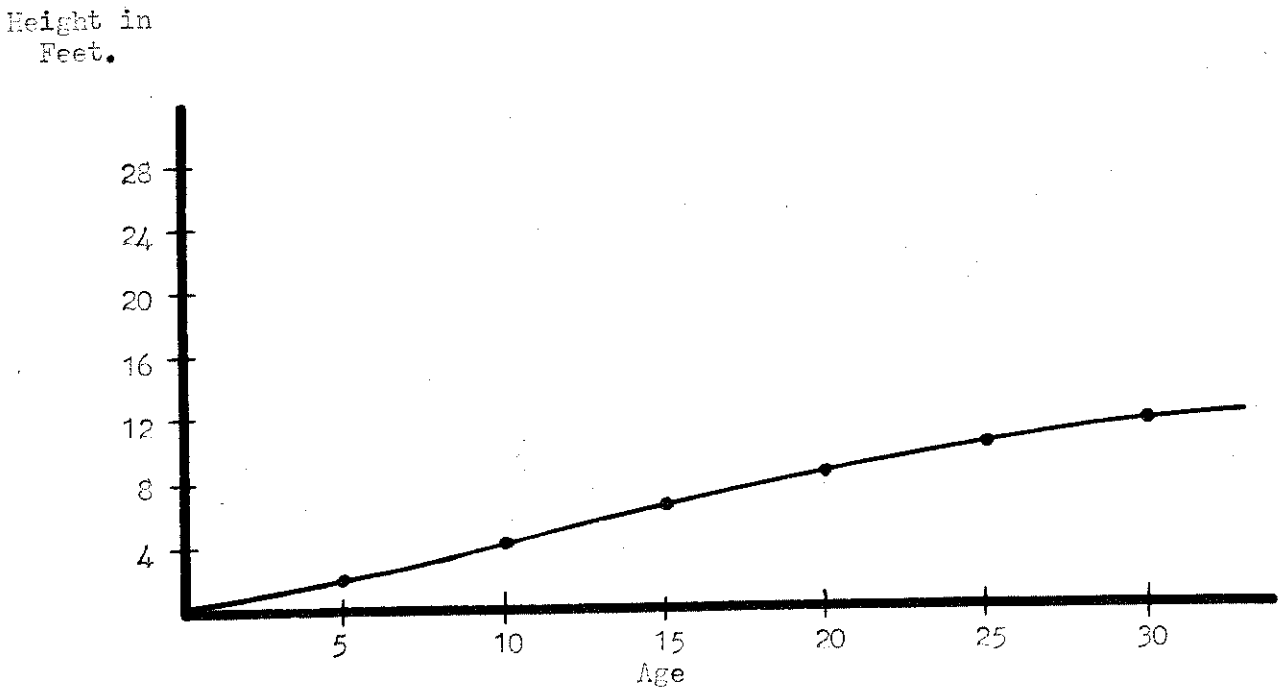
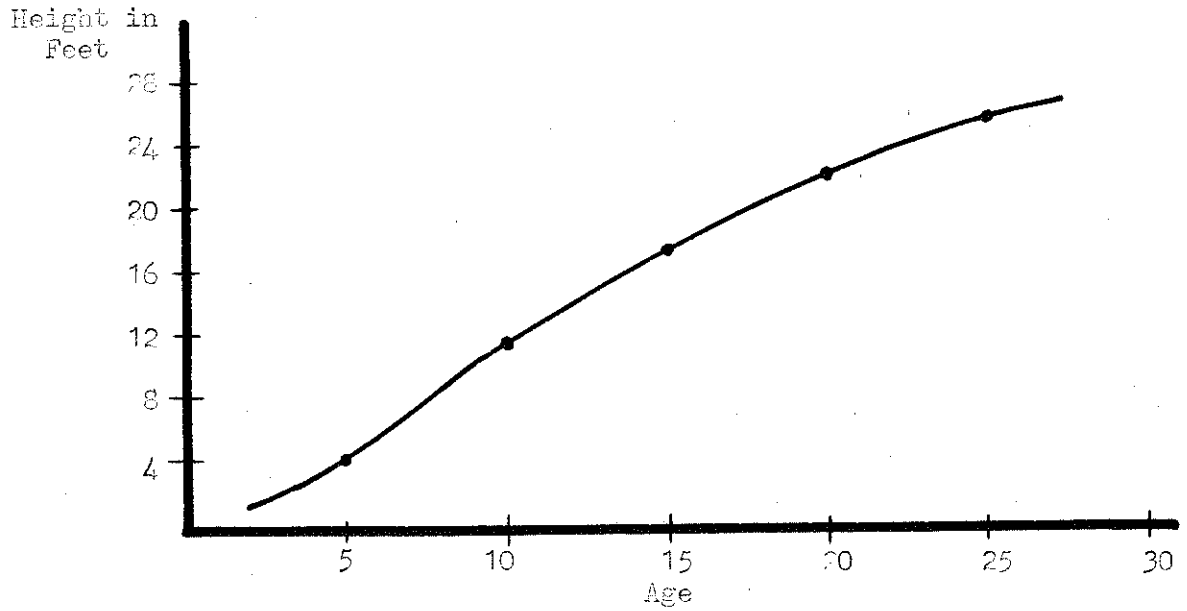


FIGURE IV

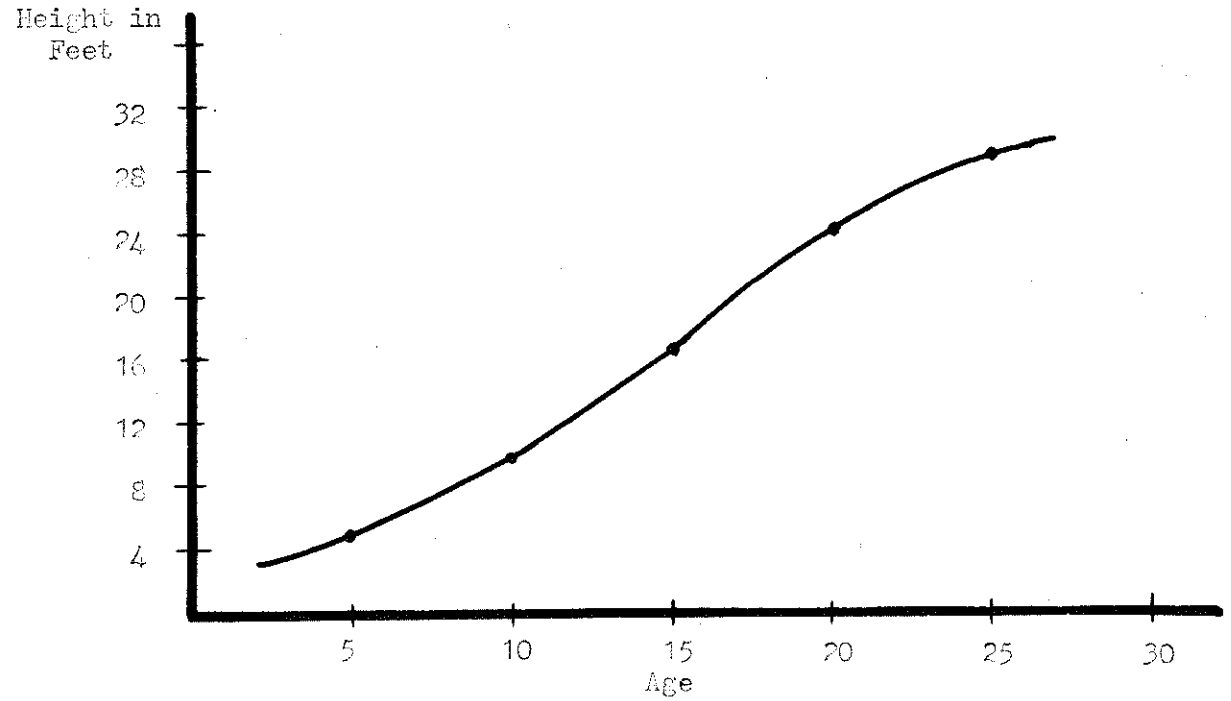
Relationship of Total Height to Age of Planted White Pine.



This data produces a plotted height which is slightly more than Expected Height Growth According to Age, illustrated by Rudolph (1950), Pp. 122. Data taken from measurements in Stands 34 - III, 44 -III and 48 - III.

FIGURE V

Relationship of Total Height to Age of Planted Red Pine.



This relationship compares favorably to that illustrated by Rudolph (1950), Pp.124. Data taken from Stands 44 - III, 48 - III and 50 - III.

APPENDIX C

Selected Bibliography, Species Mentioned and Soil Drainage Classes

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LIST OF SPECIES MENTIONED

Tree Species

Common Name	Scientific Name
Aspen	Populus grandidentata Populus tremuloides
Black birch	Betula lenta
Common alder	Alnus rugosa
Eastern hemlock	Tsuga canadensis
European larch	Larix larix
Gray birch	Betula populifolia
Norway Spruce	Picea abies
Pin cherry	Prunus pensylvanica
Pitch pine	Pinus rigida
Red maple	Acer rubrum
Red pine	Pinus resinosa
Red oak	Quercus rubra
Red spruce	Picea rubens
Scotch pine	Pinus sylvestrus
White ash	Fraxinus americana
White birch	Betula papyrifera
White pine	Pinus strobus
White spruce	Picea glauca

LIST OF SPECIES MENTIONED - CONTINUED

Shrubs and Herbacious perrenials

Common Name	Scientific Name
Bay berry	Myrica pennsylvanica
Goldenrod	Solidago sp.
Grape	Vitis sp.
High bush blueberry	Vaccinium corymbosum
Low bush blueberry	Vaccinium sp.
Milkweed	Asclepias sp.
Sweet fern	Comptonia peregrina

ANIMALS

Deer	Odocoileus virginianus
Porcupine	Erethizon dorsatum
Rabbit	Sylrilagus sp. & Lepus americanus
Weevil	Pissoides strobi

SOIL DRAINAGE CLASSES[1]

Very poorly drained. - Water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time. Soils of this drainage class usually occupy level or depressed sites and are frequently ponded. Very poorly drained soils in the podzolic soil regions commonly have dark-gray or black surface layers and are light gray, with or without mottlings, in the deeper parts of the profile. In the grassland regions, very poorly drained soils commonly have mucky surfaces with distinct evidences of gleying. These soils are wet enough to prevent the growth of important crops (except rice) without artifical drainage....

Poorly drained. - Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a slowly permeable layer within the profile, to seepage, or to some combination of these conditions. In the podzolic soil region, poorly drained soils may be light gray from the surface downward, with or without mottlings. Among the dark-colored soils of the grasslands, poorly drained soils commonly have slightly thickened dark-colored surface layers. The large quantities of water that remain in and on the poorly drained soils prohibit the growing of field crops under natural conditions in most years. Artifical drainage is generally necessary for crop production, provided other soil characteristics are favorable....

Moderately well drained. - Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer within or immediately beneath the solum, a relatively high water table, additions of water through seepage, or some combination of these conditions. Among podzolic soils, moderately well drained soils have uniform colors in the A and upper B horizons, with mottling in the lower B and in the C horizons. Among the dark-colored soils of the grasslands, profiles have thick, dark A horizons and yellowish or grayish faintly mottled B horizons....

Well-drained. - Water is removed from the soil readily but not rapidly. Well-drained soils are commonly intermediate in texture, although soils of other textural classes may also be well drained. Among the podzolic soils, well-drained soils are free of mottlings (except for fossil gley), and horizons may be brownish, yellowish, grayish, or reddish. They may be mottled deep in the C horizon or below depths of several feet. Among the dark-colored soils of the grasslands, well-drained soils have thick, dark A horizons, reddish, brownish, or yellowish B horizons, and C horizons that may or may not be mottled. Well-drained soils commonly retain optimum amounts of moisture for plant growth after rains or additions of irrigation water. This is the characteristic drainage of modal representatives of the zonal great soil groups....

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[1] From the Soil Survey Manual, USDA.